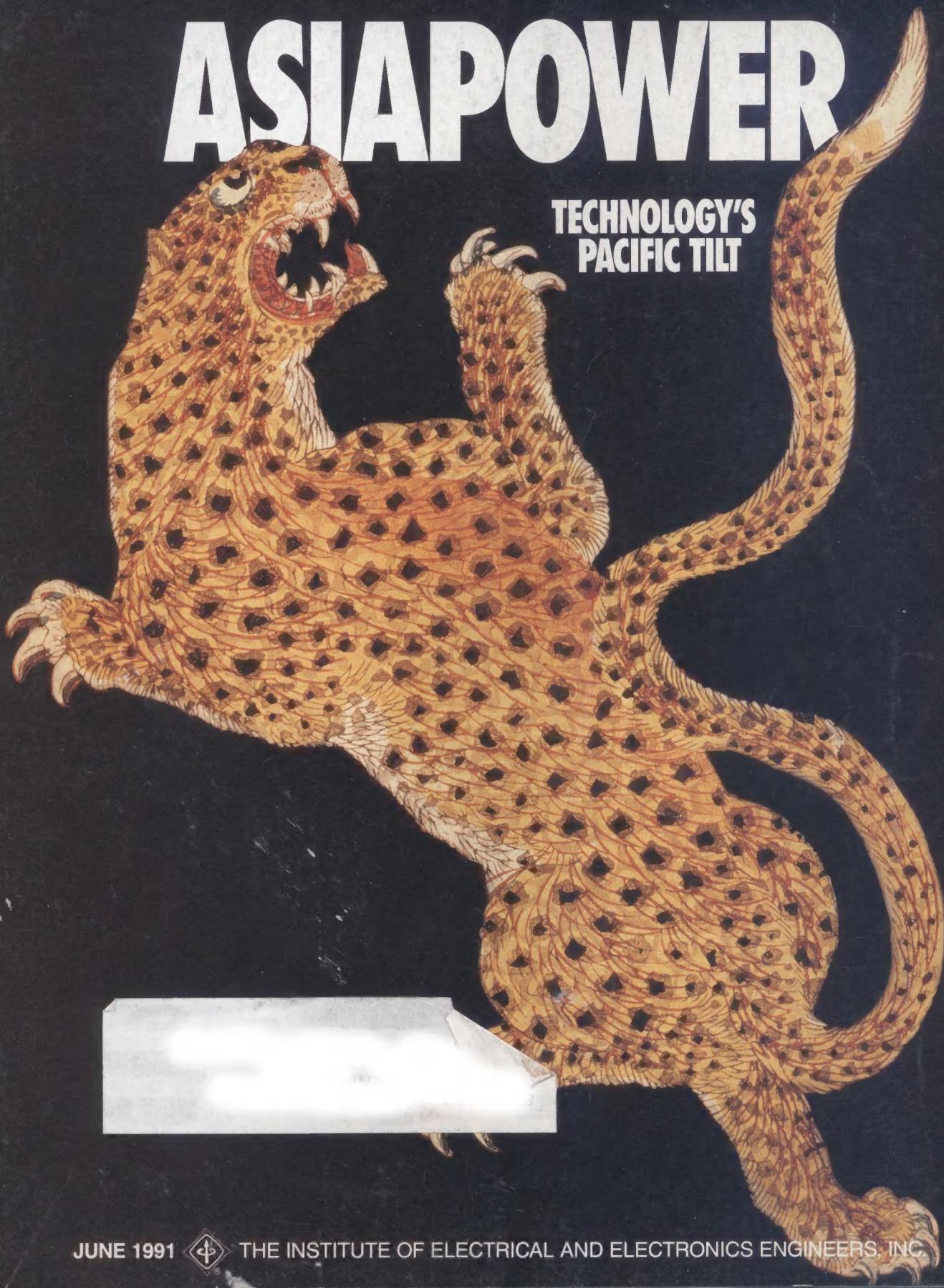


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Page Volume 27 Supplement
to Complete the Set!

In a major breakthrough in integrated circuit technology, Hughes Aircraft Company has developed a technique for producing distinct lines approximately one two-millionth of an inch on semiconductor chips. These ultrasmall features, which are 100 times smaller than most commercial integrated circuits, will play a vital role in an emerging integrated circuit technology based on quantum physics. Rather than using electron beams, they were created with a focused ion beam, since features in resist material can be defined much more accurately using ions. Scientists predict these semiconductor chips will operate 10 times faster than conventional circuits.

Technology which allows small satellite earth stations to transmit and receive data, voice, and video information in complete privacy helps smaller companies enjoy the advantages of satellite communications services. Hughes has established and is operating earth station facilities which can be shared among many users as the central control point for their independent networks. When combined with Very Small Aperture Terminal (VSAT) stations using advanced transmission techniques, Hughes' shared hub facilities allow companies to quickly and cost-effectively establish their own private, customized, satellite-based business communications networks.

Music listeners can hear dramatic 3-dimensional sound from conventional mono and stereo recording or broadcast sources, thanks to a sound reproduction technique developed by Hughes. This Sound Retrieval System (SRS) creates the ambiance and dynamic range of a live performance or studio recording. It retrieves and restores spatial information using real-time processing techniques that, like the human ear, recognize the direction from which a sound originates. Because its circuitry has been reduced to a single microchip, SRS is likely to be incorporated into a wide variety of audio products.

Pilots flying special operations helicopters on low-level missions in total darkness, smoke and fog, will be aided by the field-proven Hughes Night Vision System, designated the AN/AAQ-16. HNVS is being installed on U.S. Army MH-47E Chinooks and MH-60K Blackhawks, on U.S. Air Force MH-60G Pavehaws, and a derivative of the system has been selected for the Marine Corps' V-22 tilt rotor aircraft. The system, produced by Hughes, has been installed on several other military helicopters, including the U.S. Navy's SH-2F Light Airborne Multi-Purpose System (LAMPS) MKI. The turret mounted infrared system provides the crew with TV-like imagery on a cockpit panel display.

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Newslog

APR 10. A U.S. Department of Energy report said that a US \$1.9 billion Federal proposal to improve supercomputers—now pending before Congress—could double the speed of the average parallel supercomputer to 1.3 trillion (10^{12}) mathematical operations a second and generate more than \$10 billion in revenue for the U.S. computer industry by the end of the decade.

APR 11. Texas Instruments Inc., Hewlett-Packard Co., Canon Inc., and the Singapore Government said they have formed a venture to build a computer chip factory in Singapore. Total investment in the company, which expects to begin producing dynamic RAMs in 1993, is US \$330 million.

APR 15. ICL PLC, the UK-based computer company owned by Fujitsu Ltd. of Japan, said it had complained to the European Commission and the British Government that the French Government's aid—FFr 4 billion (US \$714 million)—to Groupe Bull SA would distort the European computer market and could encourage other computer firms to seek grants from their governments, a policy contrary to the European Community's commitment to a single open market.

APR 16. France's Groupe Bull SA increased management control of Bull HN Information Systems Inc., Billerica, Mass., by buying Minneapolis-based Honeywell Inc.'s remaining 12.8 percent stake in the company, signaling Honeywell's exit from the computer business. Groupe Bull now owns 85 percent of the company, while Tokyo's NEC Corp. owns 15 percent.

APR 18. Western Union Corp., Upper Saddle River, N.J., said it has renamed itself New Valley Corp. to protect the Western Union name in a possible bankruptcy filing in June.

APR 18. An Atlas-Centaur rocket carrying a broadcasting satellite built for Tokyo's Japanese Broadcasting Corp. (NHK) tumbled out of control shortly after liftoff from Cape Canaveral, Fla., and both rocket and satellite were destroyed by remote control. General Dynamics Corp., St. Louis, Mo., which built the rocket, said its investigation would focus on engine failure.

APR 19. Kinnevik, the Swedish communications group, and Cable & Wireless PLC of the UK said they will start a private telecommunications network, Tele2, to compete against Sweden's national agency, Televerket. Using optical-fiber cable laid alongside Sweden's main railway lines, the network will be operational this autumn and be aimed initially at businesses.

APR 19. Fujitsu Ltd., Tokyo, said it would join with CompuServe Inc., Columbus, Ohio, to begin offering computer information services—accessible through PC terminals—in Australia and New Zealand in September.

APR 19. The Jet Propulsion Laboratory, Pasadena, Calif., said no new attempt will be made to deploy the malfunctioning Galileo spacecraft until engineers can thoroughly analyze radioed data and conduct extensive ground tests. The laboratory, which manages the project for NASA, said two smaller antennas can handle all essential communications before 1995, when Galileo is scheduled to reach Jupiter.

APR 21. U.S. investigators said a group of Dutch computer intruders have openly tapped a wide range of U.S. computer networks for six months without authorization, including those at the Kennedy Space Center, the Pentagon's Pacific Fleet Command, the Lawrence Livermore National Labora-

tory, and Stanford University. Computer security experts said the group uses security loopholes pinpointed by a program written by a Cornell University student two years ago.

APR 22. Apple Computer Inc., Cupertino, Calif., said it had developed a new technique that allows circuit boards to be assembled without having to be cleaned with environmentally harmful chlorofluorocarbons (CFCs). It will eliminate its own use of CFCs by 1993.

APR 22. AT&T Co. said its AT&T Microelectronics Division would join with Tokyo's NEC Corp. to develop technologies to make future generations of semiconductors. Their goal: a 0.35-micrometer line width. The agreement comes as Washington and Tokyo are negotiating a new pact on semiconductor market access in Japan.

APR 23. The U.S. Air Force selected a team led by Lockheed Corp., Calabasas, Calif., to build a new generation of radar-evading fighter planes, the F-22, to replace the F-15 Eagle. The Air Force plans to buy 650 planes for US \$95 billion. Lockheed's two main partners are General Dynamics Corp., St. Louis, Mo., and Boeing Co., Seattle, Wash.

APR 26. The W.M. Keck Foundation said it would pay US \$74.6 million—or 80 percent of the cost—to build a twin of the world's largest telescope, Keck I, which will begin scientific observations next year atop the extinct Mauna Kea volcano in Hawaii. The addition will double Keck I's light-collecting power and reduce atmospheric distortion of galaxies near the edge of the observable universe.

MAY 1. General Dynamics Corp., St. Louis, Mo., said it expected to trim at least 27 000 from its 90 000 employees over four years—a result of the dry-

ing up of Pentagon orders.

MAY 2. Export financing agencies of the United States and Japan announced a plan in which Japanese guarantees will help finance U.S. exports to Japan and Third World countries. Japan's Ministry of International Trade and Industry will make US \$1 billion available to insure exporters' shipments.

MAY 2. The Nuclear Regulatory Commission, Rockville, Md., approved the restart of a nuclear reactor at the Browns Ferry plant in Alabama after a six-year shutdown for repairs, the longest in the history of the U.S. civilian nuclear power program.

MAY 6. NCR Corp., Dayton, Ohio, agreed to be acquired by AT&T Co. for US \$7.4 billion of AT&T stock. The agreement, made five months after a hostile bid by AT&T, will enable AT&T to expand into new markets linking computers and communications.

MAY 6. The space shuttle Discovery landed at Cape Canaveral, Fla., after an eight-day mission devoted to "Star Wars" research. The first military mission in the program to be exempted from a news blackout, it captured images of atmospheric light, gathered data to differentiate between natural and nuclear sources of X-ray radiation, and released and retrieved a satellite that studied the shuttle's own exhaust plumes in space.

Preview:

JUNE 17-19. The first international Advanced Train Control Symposium is to be held in Denver, Colo. Highlighted sessions will focus on advanced electronics to improve railroad productivity, service, and safety and on the potential of the electronically integrated railroad.

COORDINATOR: Sally Cahill

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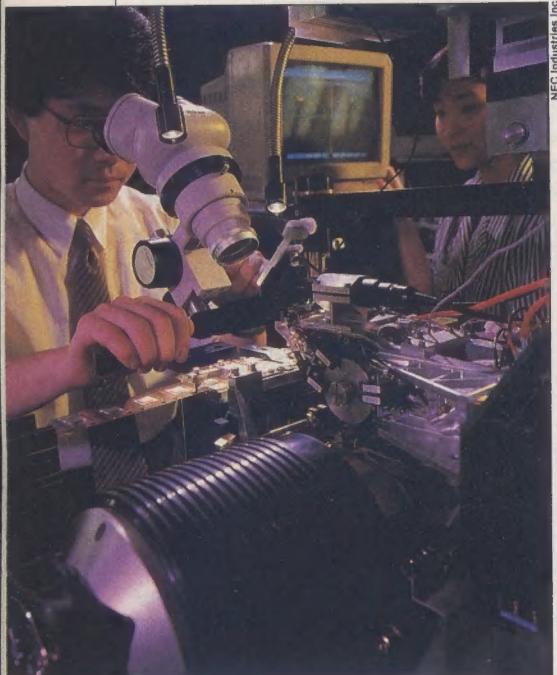
SPECIAL REPORT

24 ASIAPOWER

26 East Asia's power crescent

By ALFRED BALK

Asia now is a global power in technology. By the year 2000, it is projected to surpass the European Community and equal North America in world share of gross economic product. The fulcrum of its dynamism is a power crescent of Japan and four tigers: South Korea, Taiwan, Hong Kong, and Singapore. This special issue begins with an analysis of how this new power crescent evolved. (Below: semiconductor manufacturing at NEC.)



Bottom: Engineers at NEC Industries Inc. in Tokyo work on a television set. Above: A subway train arrives at Chungmuro Station in Seoul.

30 Poised for technological leadership

By SPECTRUM STAFF



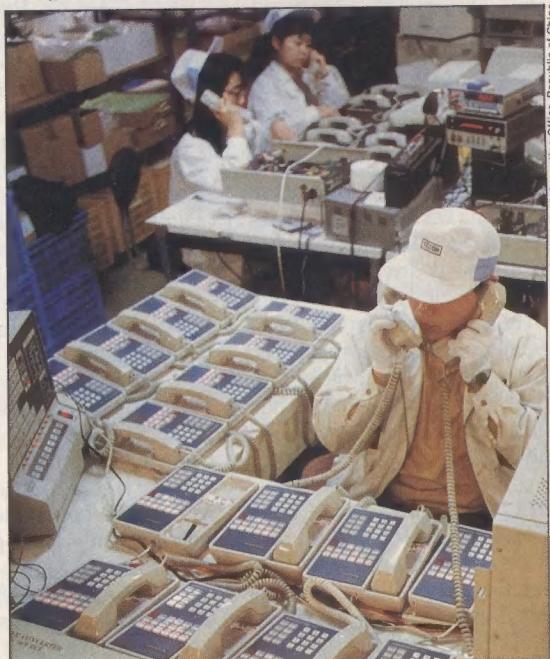
Seoul Subway Corp.

Japan, the tigers, and the tiger cubs that seek to supplant the tigers depend on innovative technology. Japan looks to such sectors as aerospace, Korea to computerized machine tools, and Taiwan to domestic IC design, for example. IC memories and portable computers remain the cornerstones of East Asia's economy. (Above: Chungmuro Station of the Seoul subway.)

49 Formula for competitiveness

By SPECTRUM STAFF

Companies in Asia's power crescent compete in traditional ways, but often their priorities differ from those of competitors elsewhere. Also, governments tend to play strong goal-setting roles. How this is done is discussed in reports on Japan's Ministry of International Trade and Industry and its clones; on subsidized science parks and institutes; and on standards and practices in educating and training technical workforces. At Tecom Corp. in Hsinchu, Taiwan, recruits (right) test phones.

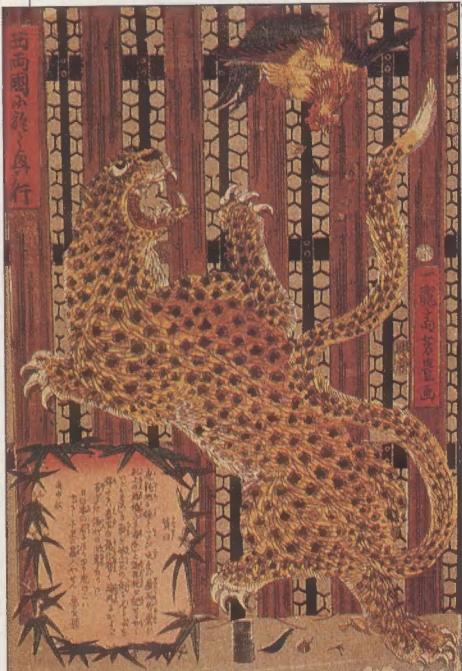


Government Information Office, Republic of China

63 What's next

By TEKLA S. PERRY

Industry leaders, economists, and government officials peer into East Asia's future. They perceive opportunity in such diverse technologies as computer software and bioelectronics, and they see challenges in protecting the environment, in ensuring a steady supply of engineers, and in focusing R&D on countries' individual needs. Only in a few countries do political questions loom large.



Daval Foundation/From the collection of Ambassador and Mrs. William Leonhart, Washington, D.C.

SPECTRAL LINES

23 Friendly second-sourcing

By DONALD CHRISTIANSEN

Do the advantages of using foreign parts in U.S. military equipment outweigh the dangers? The Persian Gulf war experience may help provide some answers.

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- 80 Coming in *Spectrum*

Cover: We chose the leopard to symbolize our theme of this special issue, ASIAPOWER. It is a detail from the woodblock print (left) "Nishiryogoku ni oite kogyo" by Yoshitoyo (1830-66). The print's inscription reads in part, "When the tiger and the leopard roar from the ground, the rooftiles will all shake, and wine on a table will tip over...." Our thanks to Ambassador and Mrs. William Leonhart for permission to use the print. See p. 24.

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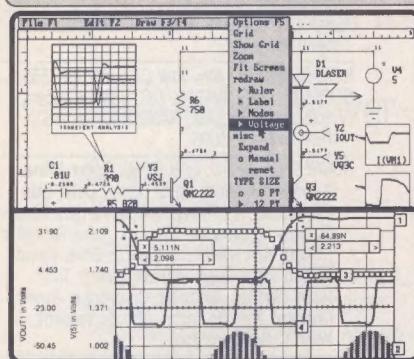
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Books

An old master's swan song

M. Granger Morgan

When he died in March 1984 at the age of 67, Ithiel de Sola Pool was arguably the foremost of the world's social scientists at work on the social and policy dimensions of information technologies. His recently published *Technologies of Freedom* had already achieved considerable critical acclaim and his

Technologies Without Boundaries: On Telecommunications in a Global Age.
Ithiel de Sola Pool (edited by Eli M. Noam), Harvard University Press, Cambridge, Mass., 283 pp., 1990, \$27.50.



edited collection *The Social Impact of the Telephone* was clearly the best available treatment of this extraordinarily difficult problem.

My colleague Marvin Sirbu, who worked closely with de Sola Pool at the Massachusetts Institute of Technology in Cambridge, tells me that de Sola Pool's style was to produce many text fragments, which he would later edit into a coherent document. When he died, he left approximately 50 computer files filled with such fragments, together with many boxes of text and notes. *Technologies Without Boundaries* owes its existence in no small part to the editorial efforts of Eli M. Noam, an accomplished scholar in information technology at Columbia University in New York City, who stitched the pieces into a book.

It is perhaps best to view this book as a set of essays, sometimes tied together with a common line of argument, but often linked only loosely. Part I, titled "Communications and the changing environment," is an excellent, simple tutorial on both telecommunication and computer technologies as well as the economic and policy dimensions of these information technologies. Electrical engineers will find the technical discussions simple and familiar, but much of the social science material will be valuable and unfamiliar. These five chapters would make an excellent introduction for use in a lower-division university course.

Part II is titled "Satellites, computers, and global relations." The five chapters in this section concentrate on the role of information technology in the process of economic development, and on the politics of international communication. There is a well-balanced and sophisticated set of arguments

on the ideologically charged issues of cultural imperialism and economic development—topics that in United Nations circles are lumped under the general heading "the new information order."

Finally, Part III on "Ecology, culture, and communications technology" elaborates several technology assessment and forecasting themes that are introduced in Part I. This is done by exploring how information technologies may affect future human settlement patterns, and by examining issues in technology and culture, focusing particularly on the future of books.

Much of the material in this collection is interesting and insightful. Readers new to the field will find excellent treatments of many of the most important issues. Old hands will find thoughtful reflections and occasional new perspectives. But because divestiture was only beginning when de Sola Pool died, some important recent developments are not addressed.

Occasionally, too, a discussion needs more refinement. For example, the argument that the position of poor countries will worsen because the development of database publication may limit their access to such material ignores the potential implications of cheap, very high-density, portable storage media such as optical discs. Once a library can be easily reproduced, and even carried in a suitcase, such arguments will begin to lose merit. Finally, more attention could have been paid to several issues, such as security and privacy and the role of standards in technological evolution.

But these criticisms are minor. Had he lived, perhaps de Sola Pool would have filled such gaps. As it is, we should be grateful to Eli Noam for granting us easy access to this large set of final insights from a fine scholar.

M. Granger Morgan (F) is head of the department of engineering and public policy at Carnegie Mellon University in Pittsburgh, where he is also a professor in the department of electrical and computer engineering. His research deals principally with problems of technology and policy. He is a member of THE INSTITUTE's editorial board.

COORDINATOR: Glenn Zorpette

Recent books

Programmer's Guide to Netware. Rose, Charles G., McGraw-Hill, New York, 1990, 933 pp., \$49.95.

Applied Optics Digest. Dainty, J.C., IOP Publishing, Bristol, UK, 1990, 330 pp., \$50.

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Calendar

Meetings, Conferences and Conventions

JUNE

Second International Conference on Magnetic Recording Systems (MAG et al.); June 12-15; Hidden Valley Retreat, Pittsburgh; Gordon Hughes, Seagate Technology, 900 Disc Dr., Scotts Valley, Calif. 95066; 408-439-2626; fax, 408-438-4190.

Device Research Conference (ED); June 16-19; University of Colorado, Boulder; Larry Coldren, University of California, Department of Electrical Engineering and Computer Engineering, Santa Barbara, Calif. 93106; 805-893-4486.

Eighth IEEE Pulsed Power Conference (ED); June 17-19; Sheraton Island Harbor Hotel, San Diego, Calif.; Roger White, Maxwell Laboratories Inc., 8888 Balboa Ave., San Diego, Calif. 92123; 619-576-7884.

Digital Cross-Connect Systems Workshop IV (COM); June 17-20; Banff Park Lodge, Banff, Alta., Canada; J.H. Simester, AT&T Bell Laboratories, Room 4J-526, Crawfords Corner Road, Holmdel, N.J. 07733; 908-949-7336.

28th Design Automation Conference (CS); June 17-21; Moscone Center, San Francisco; Alfred E. Dunlop, MP Associates Inc., 7490 Clubhouse Rd., Suite 102, Boulder, Colo., 80301; 303-530-4333.

Joint Magnetism and Magnetic Materials-Intermag Conference (MAG); June 18-21; Pittsburgh Hilton, Pittsburgh; Diane Sueters, Conference Coordinator, 655 15th St., N.W., Suite 300, Washington, D.C. 20005; 202-639-5088.

Workshop on High-Speed

Digital Subscriber Lines (COM); June 19-20; Sunnyvale Hilton Hotel, Sunnyvale, Calif.; James Dixon, Bellcore, 445 South St., Morristown, N.J. 07962-1910; 201-829-4954.

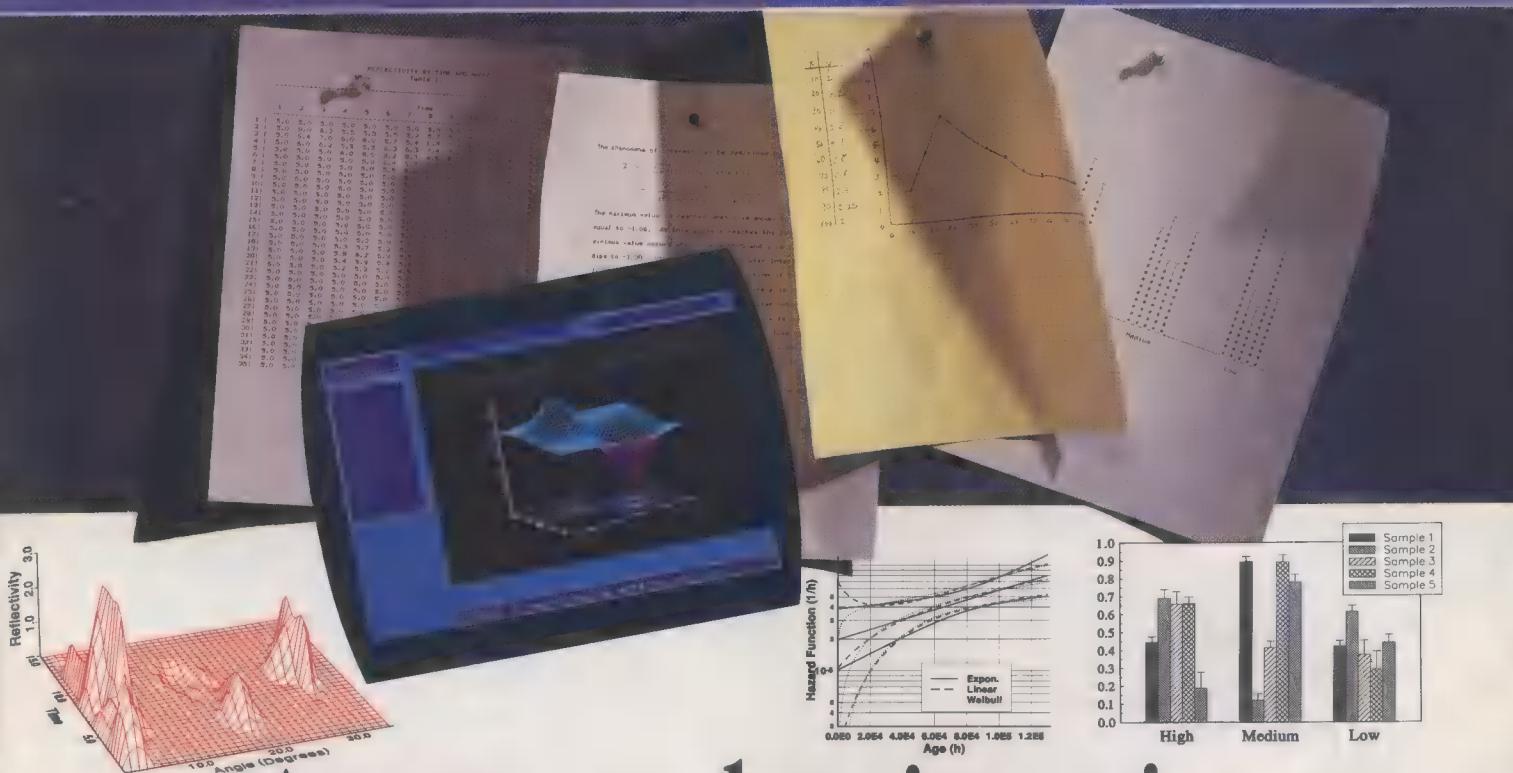
SSIT Interdisciplinary Conference (SSIT); June 21-22; Ryerson Polytechnical Institute, Toronto; D. Falkner, Program Director Conferences, Ryerson Polytechnical Institute, 350 Victoria St., Toronto, Ont., M5B 2K3, Canada; 416-979-5184.

International Conference on Communications (COMP); June 23-26; Denver Technical Center, Hyatt and Sheraton; Russell Johnson, Western Telecommunications Inc., 4643 S. Ulster St., Suite 400, Denver, Colo. 80237; 303-721-5650.

Antennas and Propagation Society International Symposium and URSI National Radio Science Meeting (AP); June 23-27; University of Western Ontario, London, Ont., Canada; A.R. Webster, Faculty of Engineering Science, University of Western Ontario, London, Ont. N6A 5B9, Canada; 519-679-6294.

IEEE members attend more than 5000 IEEE professional meetings, conferences, and conventions held throughout the world each year. For more information on any meeting in this guide, write or call the listed meeting contact. Information is also available from: Conference Services Department, IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855; 908-562-3878; submit conferences for listing to: Rita Holland, *IEEE Spectrum*, 345 E. 47th St., New York, N.Y. 10017; 212-705-7569.

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Calendar

International Symposium on Information Theory (IT); June 23-28; Budapest Conference Center, Budapest, Hungary; Anthony Ephremides, Department of Electrical Engineering, University of Maryland, College Park, Md. 20742; 301-405-3641.

Computer Assurance Conference-Compass '91 (AES); June 24-27; National Institute of Standards and Technology, Gaithersburg, Md.; Andrew Moore, Naval Research Laboratory, Code 5542, Washington,

D.C. 20375; 202-767-6698.

Power Electronics Specialist Conference-PESC '91 (PEL); June 24-28; Massachusetts Institute of Technology (MIT), Cambridge; Martin Schlecht, MIT, Room 39-553, Cambridge, Mass. 02139; 617-253-3407.

Transducers '91: International Solid-State Sensors and Actuators Conference (ED); June 24-28; Hyatt Regency Hotel, San Francisco; Richard S. Muller, 497 Cory Hall, Berkeley Sensor and Actuators

Center, University of California at Berkeley, Berkeley, Calif. 94720; 415-642-0614.

21st International Symposium on Fault-Tolerant Computing (C); June 25-27; The Grand Hotel, Montreal; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

American Control Conference-ACC '91 (CS); June 26-28; Boston Park Plaza Hotel & Towers, Boston; Timothy Johnson, General Electric Co., Research and Development, KWD 217, Box 8, Schenectady, N.Y. 12345; 518-387-5096.

Communications Theory Workshop (COM); June 30-July 6; Rodos Palace Hotel, Rhodes, Greece; Nick Zervos, AT&T Bell Laboratories, 200 Laurel Ave., Room 3K-215, Middletown, N.J. 07748; 908-957-2085; fax, 908-957-7307; or Zeus Network, 566 7th Ave., 6th Floor, New York, N.Y. 10018; 212-221-0006; fax, 212-764-7912.

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JULY

International Joint Conference on Neural Networks-IJCNN '91 (NN); July 8-12; Sheraton Seattle Hotel, Seattle, Wash.; Sarah Eck, Conference Management, University of Washington, 5001 25th Ave., N.E., GH-22, Seattle, Wash. 98195; 206-543-0888; fax, 206-545-9359.

Third International Conference on Properties and Applications of Dielectric Materials (DEI); July 8-12; Waseda University International Conference Center, Tokyo; T. Tanaka, CRIEPI, 2-11-1 Iwato-Kita, Komae-shi, Tokyo 201, Japan; (81+3) 480 2111.

28th Nuclear and Space Radiation Effects Conference (IEEE Nuclear and Plasma Sciences Society); July 15-19; Town and Country Hotel, San Diego, Calif.; James R. Schwank, Sandia National Laboratories, Division 2144, Box 5800, Albuquerque, N.M. 87185; 505-846-8485.

Power Engineering Society Summer Meeting (PE); July 28-Aug. 1; Marriott Hotel, San Diego, Calif.; T.M. Winter, San Diego Gas & Electric Co., 101 Ash St., Box 1831, San Diego, Calif. 92112; 714-232-4252.

AUGUST

26th Intersociety Energy Conversion Engineering Conference-IECEC '91 (ED); Aug. 3-9; Boston Marriott Hotel, Boston; Patrick Bailey, Lockheed Missiles & Space Co., 1111 Lockheed Way (59-32-

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Calendar

535), Sunnyvale, Calif. 94088; 408-756-4268.

Cornell Conference on Advanced Concepts in High-Speed Semiconductor Devices and Circuits (ED); Aug. 5-7; Cornell University, Ithaca, N.Y.; R.J. Trew, North Carolina State University, Electrical and Computer Engineering Department, Box 7911, Raleigh, N.C. 27695; 919-737-2336.

International Symposium on Electromagnetic Compatibility—EMC '91 (EMC et al.); Aug. 13-15; Hyatt Cherry Hill, Cherry Hill, N.J.; Henry W. Ott, 45 Baker Rd., Livingston, N.J. 07039; 201-386-6660.

First International Conference on the Applications of Diamond Films and Related Materials (ED); Aug. 20-22; Auburn University Hotel and Conference Center, Auburn, Ala.; Y. Tzeng, Department of Electrical Engineering, Auburn University, Auburn, Ala. 36849; 205-844-1869 or 2427; fax, 205-844-2433 or 1809.

Fourth International Vacuum Microelectronics Conference (ED); Aug. 22-24; Nagahama Royal Hotel, Shiga, Japan; Junzo Ishikawa, Department of Electronics, Kyoto University, Sakyo-ku, Kyoto 606, Japan; (81+75) 753 5325 or 5021.

Workshop on the Future of Electronic Power Processing and Conversion (IA); Aug. 28-29; Kruger National Park, South Africa; William Portnoy, Texas Tech University, Department of Electrical Engineering, Box 4439, Lubbock, Texas 79409-3102; 806-742-3533.

Region 10 Conference on Energy, Computer, Communication and Control Systems—Tencon '91 (C, COM, et al.); Aug. 28-30; Taj Palace InterContinental, New Delhi, India; K.R.S. Murthy, AT&T Bell Laboratories, Crawfords Corner Road, Room 2N-437, Holmdel, N.J. 07733; 908-949-4850; or H.L. Bajaj, B-101, Hillview Apartments, Vasant Vihar, New Delhi 110 057, India; (91+11) 360 412.

SEPTEMBER

Bipolar Circuits and Technology Meeting (ED); Sept. 9-10; Minneapolis Marriott Hotel, Minneapolis, Minn.; John Shier, 2401 E. 86th St., Bloomington, Minn. 55425; 612-851-5228.

Petroleum and Chemical Industry Technical Conference (IA); Sept. 9-11; Royal York, Toronto; Barry Wiseman, Reliance Electric Co., 5220 Creekbank Rd., Mississauga, Ont. L3W 1X1, Canada; 416-625-8112.

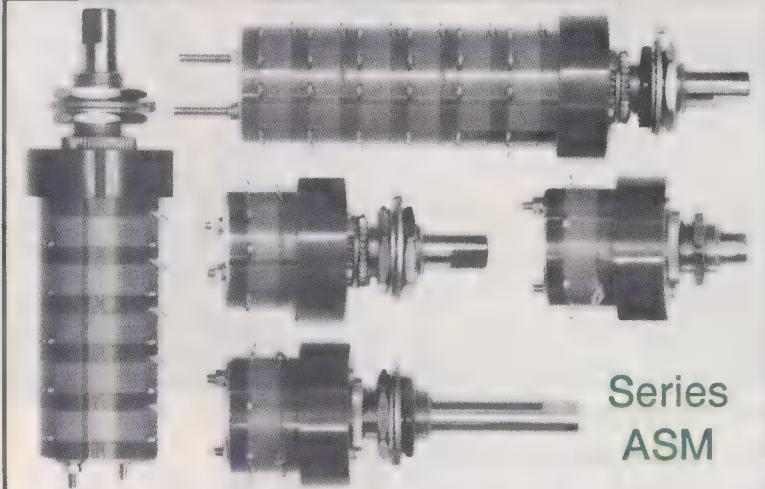
International Symposium on Gallium Arsenide and Related Compounds (ED); Sept. 9-12; Sheraton Hotel and Towers, Seattle, Wash.; L. Ralph Dawson, Sandia National Laboratories, Division 1144, Albuquerque, N.M. 87185; 505-844-8920.

Third International Conference on Microstructures in Biological Research (ED); Sept. 9-12; Fort McGruder Inn and Conference Center, Williamsburg, Va.; Martin Peckerar, Naval Research Laboratory, 4555 Overlook Ave., Washington, D.C. 20375-5000; 202-767-3150.

Seventh Multidimensional Signal Processing Workshop (SP); Sept. 23-25; Whiteface Inn, Lake Placid, N.Y.; John Woods, Computer and Systems Engineering, Rensselaer Polytechnic Institute, Troy, N.Y. 12181; 518-276-6079.

18th International Conference on Computers in Cardiology (COMP et al.); Sept. 23-26; Venice, Italy; Corso Stati Uniti 4, 35020 Padova, Italy; (39+49) 829 5702.

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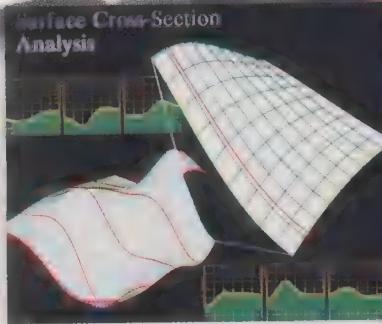


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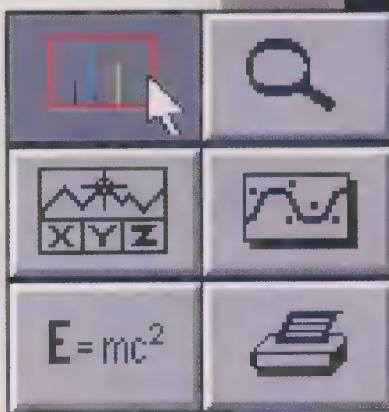
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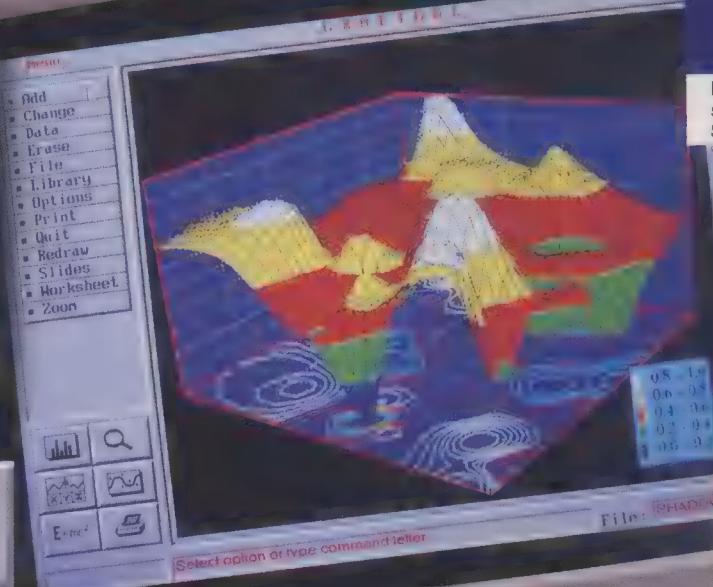
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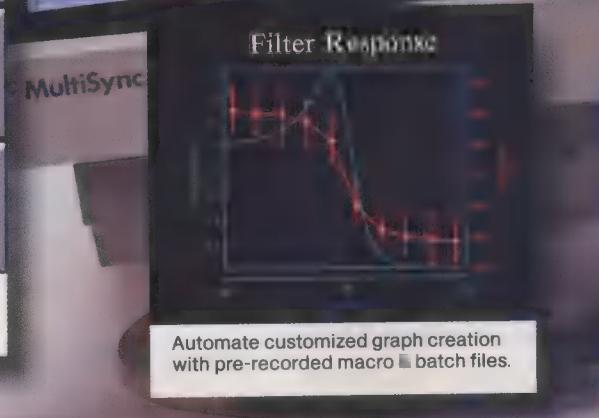
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Calendar

Fourth Annual International Application Specific Integrated Circuits Conference and Exhibit (IEEE Rochester et al.); Sept. 23-27; Rochester Riverside Convention Center, Rochester, N.Y.; Kenneth W. Hsu, Department of Computer Engineering, Rochester Institute of Technology, Rochester, N.Y. 14623; 716-475-2655.

Industry Applications Society Conference (IA); Sept. 28-Oct. 4; Hyatt Regency, Dearborn, Mich.; William Moylan, Moy-

lan Engineering Associates, 13530 Michigan Ave., Dearborn, Mich. 48126; 313-582-9880.

OCTOBER

VLSI in Computers and Processors-ICCD '91 (ED); Oct. 5-9; Cambridge, Mass.; Dwight Hill, AT&T Bell Laboratory, 3D-446, 600 Mountain Ave., Murray Hill, N.J. 07974; 201-582-7766.

International Joint Power Generation Conference-IJPGC '91 (PE); Oct. 6-9;

Town and Country Hotel, San Diego, Calif.; M. Scalice, ASME, 345 E. 47th St., New York, N.Y. 10017; 212-705-7053.

37th Holm Conference on Electrical Contacts (CHMT); Oct. 6-9; Marriott Downtown, Chicago; Conference Registrar, IEEE Inc., 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 908-562-3863.

22nd Photovoltaic Specialists Conference (ED); Oct. 7-11; Riviera Hotel, Las Vegas, Nev.; Howard E. Pollard, Ford Aerospace, 3939 Fabian Way, M.S. G45, Palo Alto, Calif. 94303-4695; 415-852-5131.

Fourth International Conference on Amorphous and Crystalline Silicon Carbide and Other III-IV Materials (ED); Oct. 10-11; Santa Clara University, California; Cary Yang, 408-554-6814.

International Display Research Conference (ED); Oct. 15-17; Hyatt Islandia Hotel, San Diego, Calif.; Andras Lakatos, Xerox Corp., 800 Phillips Rd., Webster, N.Y. 14580; 716-422-9700.

1991 GaAs Reliability Workshop (ED); Oct. 20; Monterey, Calif.; Anthony Immorlica, General Electric, Electronics Laboratory, Electronics Park, Syracuse, N.Y. 13221; 315-456-3514.

GaAs Integrated Circuits Symposium (ED); Oct. 20-23; Monterey Sheraton Hotel, Monterey, Calif.; Suzanne Kuntz, Courtesy Associates, 655 15th St., N.W., Suite 300, Washington, D.C. 20005; 202-347-5900.

Military Communications Conference-Milcon '91 (COM); Oct. 20-23; McLean Hilton, Virginia; Fay Brady, Mitre Corp., 7525 Colshire Dr., McLean, Va. 22102; 703-883-6733.

Vehicle Navigation and Information Systems Conference-VNIS '91 (VT); Oct. 20-23; Troy, Mich.; Mark K. Krage, General Motors Research Laboratories, Department 18, 30500 Mound Rd., Warren, Mich. 48090; 313-986-2976.

Advanced Semiconductor Manufacturing Conference and Workshop (ED); Oct. 21-22; World Trade Center, Boston, Mass.; Margaret Bachmeyer; 2000 L St., N.W.; Suite 200, Washington, D.C. 20036; 202-457-9584.

NOVEMBER

International Conference on Computer-Aided Design-ICCAD '91 (ED); Nov. 11-14; ICCAD, 1730 Massachusetts Ave., Washington, D.C. 20036-1903; 202-371-0101.



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Calendar

Third Topical Conference on Emerging Technologies in Materials (ED); Nov. 17-22; Los Angeles Hilton Hotel, Los Angeles; Stevin H. Gehrke, Department of Chemical Engineering, University of Cincinnati, Mail Location 171, Cincinnati, Ohio 45221-0171; 513-556-2766.

DECEMBER

International Electron Devices Meeting (ED); Dec. 8-11; Washington Hilton Hotel, Washington, D.C.; Melissa Widerkehr, c/o Courtesy Associates Inc., 655 15th St., N.W., Suite 300, Washington, D.C. 20005; 202-639-4990.

Ultrasonics Symposium (UFFC); Dec. 8-11; Hilton Hotel at Disney World, Orlando, Fla.; Don Malocha, Department of Electrical Engineering, University of Central Florida, Orlando, Fla. 32816; 407-275-2414.

22nd Annual Semiconductor Interfaces Specialist Conference (ED); Dec. 11-14; Orlando, Fla., Steve Lyon, Department of Electrical Engineering, Princeton University, Princeton, N.J. 08544; 609-258-4635.

Recent books

(Continued from p. 6)

The C Primer. Hancock, Les, et al., McGraw-Hill, New York, 1991, 370 pp., \$24.95.

Expert Planning Systems. Ed. Boardman, J.T., et al., Institution of Electrical Engineers, London, 1990, 261 pp., US \$84.

IBM's 360 and Early 370 Systems. Pugh, Emerson W., et al., MIT Press, Cambridge, Mass., 1991, 819 pp., \$37.50.

Satellite Operations. Garner, John T., et al., Ellis Horwood, London, 1990, 160 pp., \$71.50.

Brushless Servomotors. Dote, Kinoshita, Oxford University Press, New York, 1990, 261 pp., \$95.

Semiconductor Industry. Morris, Peter R., Peter Peregrinus, London, 1991, 171 pp., \$64.

Supertech: How America Can Win. Donlan, Thomas G., Business One Irwin, Homewood, Ill., 1991, 325 pp., \$22.95.

Applications Strategies for Risk Analysis. Charette, Robert N., Intertext/McGraw-Hill,

New York, 1991, 570 pp., \$49.95.

Technical Writing for Private Industry. Koenigseck, Edward von, et al., Krieger Publishing, Malabar, Fla., 1990, 150 pp., \$24.50.

Artificial Intelligence. Mirzai, A.R., MIT Press, Cambridge, Mass., 1990, 304 pp., \$39.95.

Design of Very High-Level Computer Languages. Klerer, Melvin, McGraw-Hill, New York, 1991, 228 pp., \$49.95.

Handbook of Genetic Algorithms. Davis, Lawrence, Van Nostrand Reinhold, New York, 1991, 385 pp., \$49.95.

Digital System Design. Lin, Wen C., CRC Press, Boca Raton, Fla., 1990, 473 pp., \$49.95.

Microprocessors and Microcomputer-Based System Design. Rafiquzzaman, Mohamed, CRC Press, Boca Raton, Fla., 1990, 1075 pp., \$49.95.

Interferometry in Radioastronomy and Radar Techniques. Wohlleben, R., et al., Kluwer Academic, Dordrecht, the Netherlands, 1990, 210 pp., \$84.

(Continued on p. 72B)

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Third Topical Conference on Emerging Technologies in Materials (ED); Nov. 17-22; Los Angeles Hilton Hotel, Los Angeles; Stevin H. Gehrke, Department of Chemical Engineering, University of Cincinnati, Mail Location 171, Cincinnati, Ohio 45221-0171; 513-556-2766.

DECEMBER

International Electron Devices Meeting (ED); Dec. 8-11; Washington Hilton Hotel, Washington, D.C.; Melissa Widerkehr, c/o Courtesy Associates Inc., 655 15th St., N.W., Suite 300, Washington, D.C. 20005; 202-639-4990.

Ultrasonics Symposium (UFFC); Dec. 8-11; Hilton Hotel at Disney World, Orlando, Fla.; Don Malocha, Department of Electrical Engineering, University of Central Florida, Orlando, Fla. 32816; 407-275-2414.

22nd Annual Semiconductor Interfaces Specialist Conference (ED); Dec. 11-14; Orlando, Fla., Steve Lyon, Department of Electrical Engineering, Princeton University, Princeton, N.J. 08544; 609-258-4635.

Recent

(Continued from p. 6)

The C Primer, Hancock, Hill, New York, 1991,

Expert Planning System, T., et al., Institution of London, 1990, 261 pp.

IBM's 360 and Early 370 Systems, W., et al., MIT Press, Cambridge, Mass., 1991, 819 pp., \$35.

Satellite Operations, G., Ellis Horwood, London, 1990, 261 pp., \$71.50.

Brushless Servomotors, J., Oxford University Press, Oxford, 1990, 261 pp., \$95.

Semiconductor Industry, Peter Peregrinus, London, 1990, 261 pp., \$64.

Supertech: How America Gained Its Lead in High Technology, Thomas G., Business Week Books, New York, 1991, 325 pp., \$19.95.

Applications Strategies, Charette, Robert N., Int'l. Electronics

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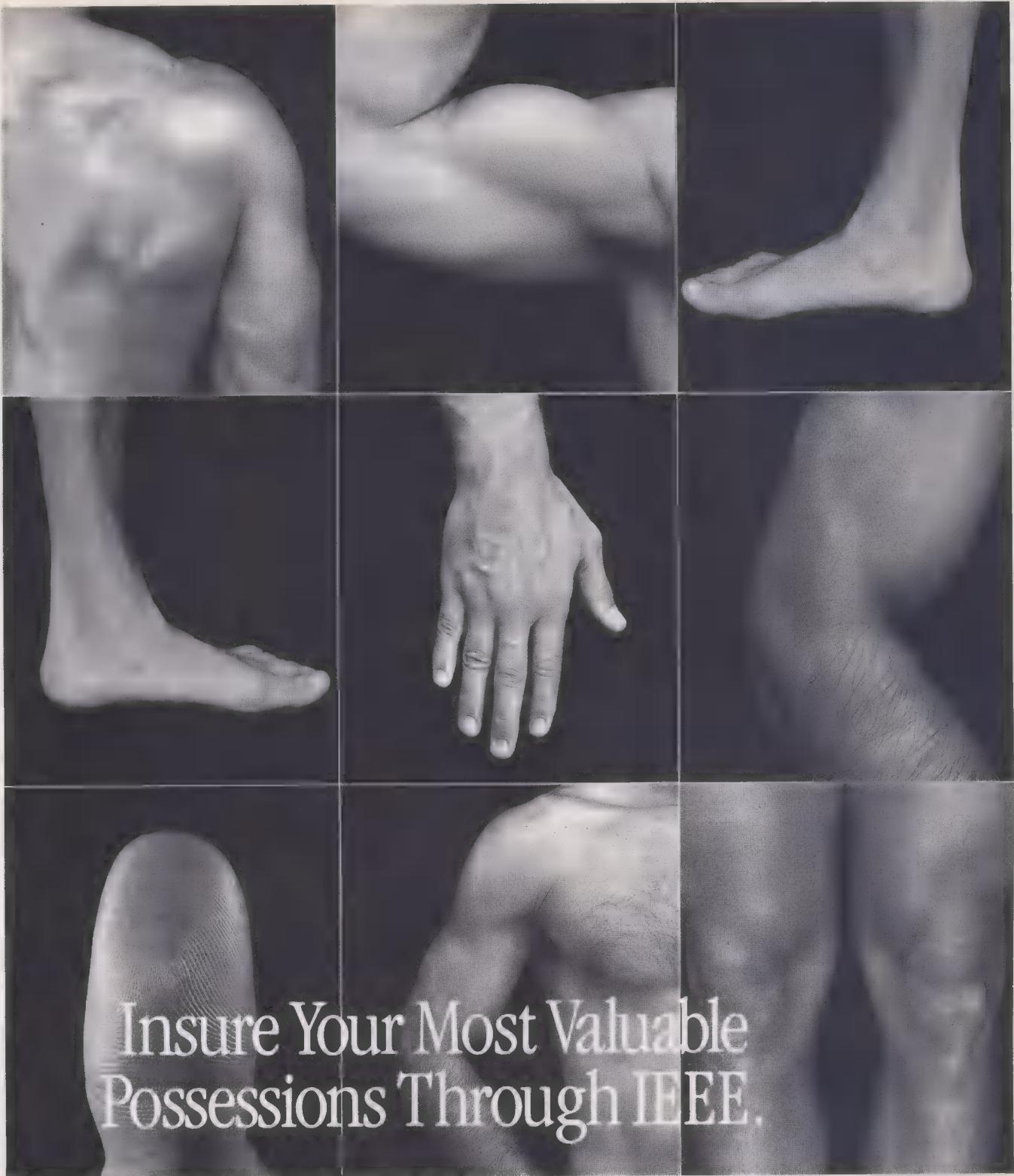


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Speakout

Engineers teach for far too little

Engineers donate a great deal of their time organizing and teaching classes for companies in the electronics industry. The value of those classes to company employees, who are the students, is enormous. Yet the engineering instructors are paid a pittance for this work. They should demand, and receive, more.

I think of engineering education at three levels:

- Undergraduate, in which a corpus of standard material is taught from textbooks. The students learn to think in quantitative terms.
- Early graduate, which is an extension of undergraduate education. At this level, notes sometimes replace textbooks.
- Specialized classes, which are at the leading edge of technology. The instructor must systematize the body of knowledge, then teach it. The students are almost exclusively professionals sent by their companies, often across national boundaries.

I am concerned with that third level. Many engineers teach specialized graduate courses. Some of those are run by profit-making companies, but most are run by universities at night or in short, one- to two-week sessions. A company that sends an employee to one of these classes gains at least a man-year of knowledge (worth more than US \$150 000, including the overhead) that the employee otherwise would have had to acquire on his or her own. That means the company's schedule for bringing its engineers up to the state-of-the-art technology is moved ahead a calendar year.

Students fortunate enough to attend a course taught by an ultra-experienced electronics superstar gain immeasurably from learning the arcane knowledge and folklore, the analytic techniques, and the structure of the industry. Such information is not obtainable at any price by on-the-job training. Indeed, many engineers would never learn such details.

How much time does it take for an experienced engineer to prepare a course at the third, leading-edge-of-technology level? Based on 10 classes I have given over 30 of my 35 professional years, it requires 10-15 hours of preparation time and 1 hour of post-class time per class hour. The time is needed to collect visual materials and to organize the core of knowledge to be taught (there is usually no textbook, which is why the course is given). That material must then be

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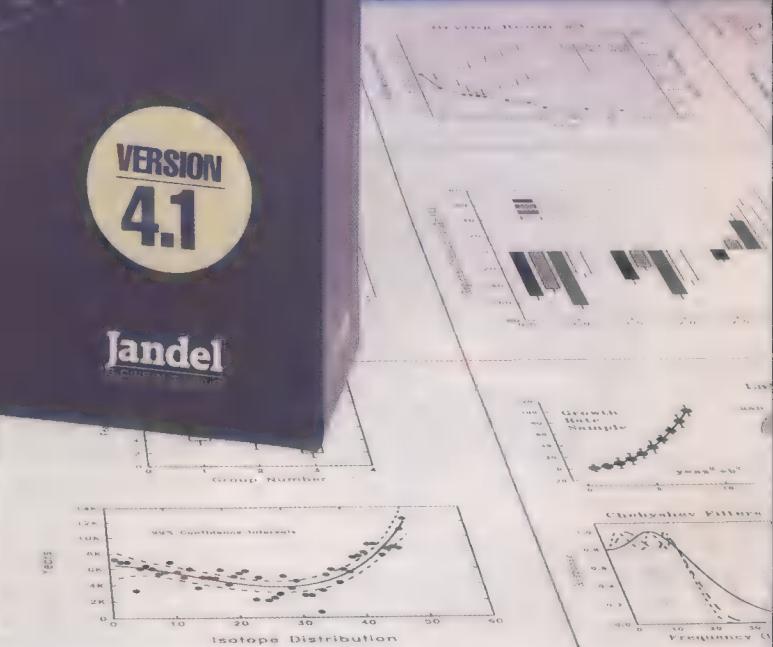
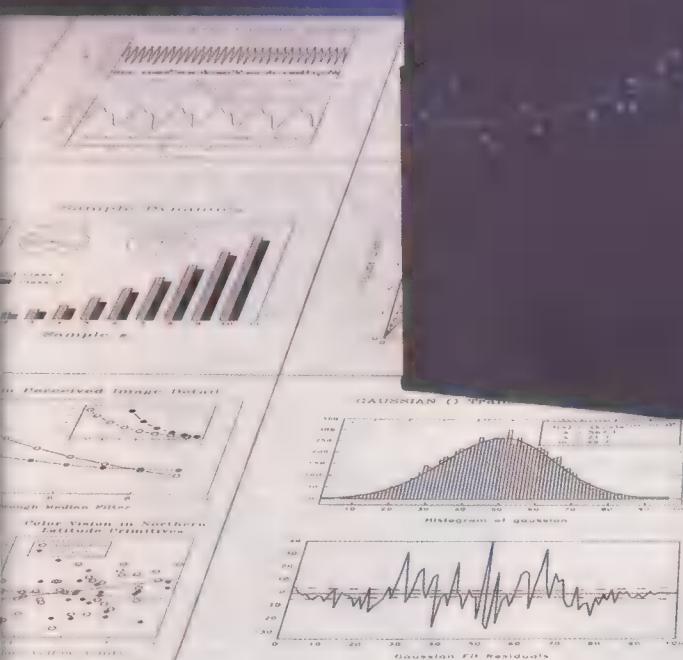
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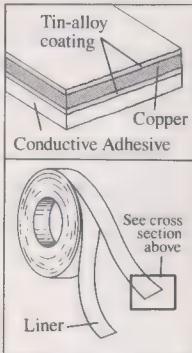
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14

Speakout

turned into notes (text, equations, and drawings), as well as slides, computer programs, projection transparencies, and quizzes.

Several visits to a library are needed to verify details, tie the material to adjacent disciplines, and prepare a current list of references. A five-day class requires about 30 hours in the classroom and 20 hours of administrative time (for contracts, publicity, and liaison with the school management).

Thus, the total first-time effort to prepare a class is more than 450 hours. A senior lawyer, who has the same position in the legal field as a senior engineer in engineering, would bill at least \$350 per hour. (Top Los Angeles lawyers bill closer to \$700 per hour, according to a recent survey by *The Los Angeles Times*, or \$160 000.) A school could pay that kind of fee if tuition were \$20 000 per student for ■ typical 25-student class. If the class were repeated, preparation would be reduced to 6 hours per class hour, which could warrant ■ lawyer-like fee of \$600 per hour.

How much do these specialized instructors actually earn? At most Southern California schools—where tuition costs \$1000 per student—a one-week day class or a 15-week night class earns the teaching engineer \$2500 to \$8000, no matter the level of instruction. Hence, if the senior engineer values his time at the same rate as does a lawyer (who is also paid for his technical knowledge), the engineer is contributing \$150 000 out of his or her own pocket. This contribution is made not to the school but to the companies who pay bargain tuitions for the knowledge gained.

The free market allows such low rates because engineers are willing to teach cheaply. The more senior engineers have already established their reputations and so do it for the love of teaching. Others are retired and enjoy remaining involved. Junior engineers, whose instruction is usually confined to the theoretical aspects of ■ subject, usually conduct classes for less advanced students.)

Engineering societies should encourage highly specialized engineers to teach. But senior engineers should demand economically justified rates, leaving the low-level teaching to the debutants. I am certain that companies in the competitive sector of the U.S. economy would pay \$20 000 tuition to bring their engineers up to speed quickly. Indeed, concentrated specialized education is the quickest way for them to raise productivity.

Myron Kayton

Myron Kayton (F) is a consultant in Santa Monica, Calif., specializing in vehicle automation. The opinions expressed here are his own.

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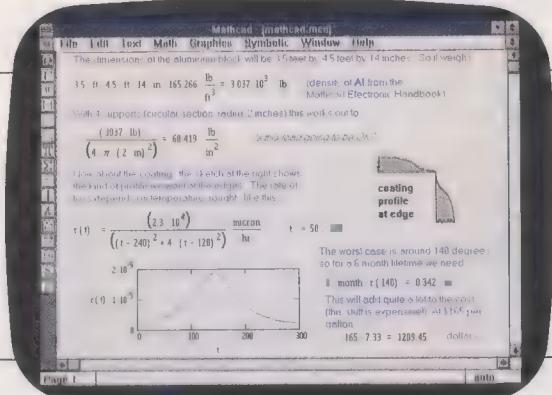
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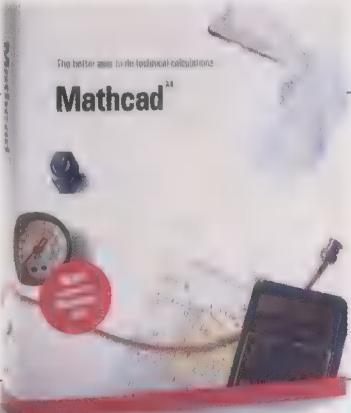
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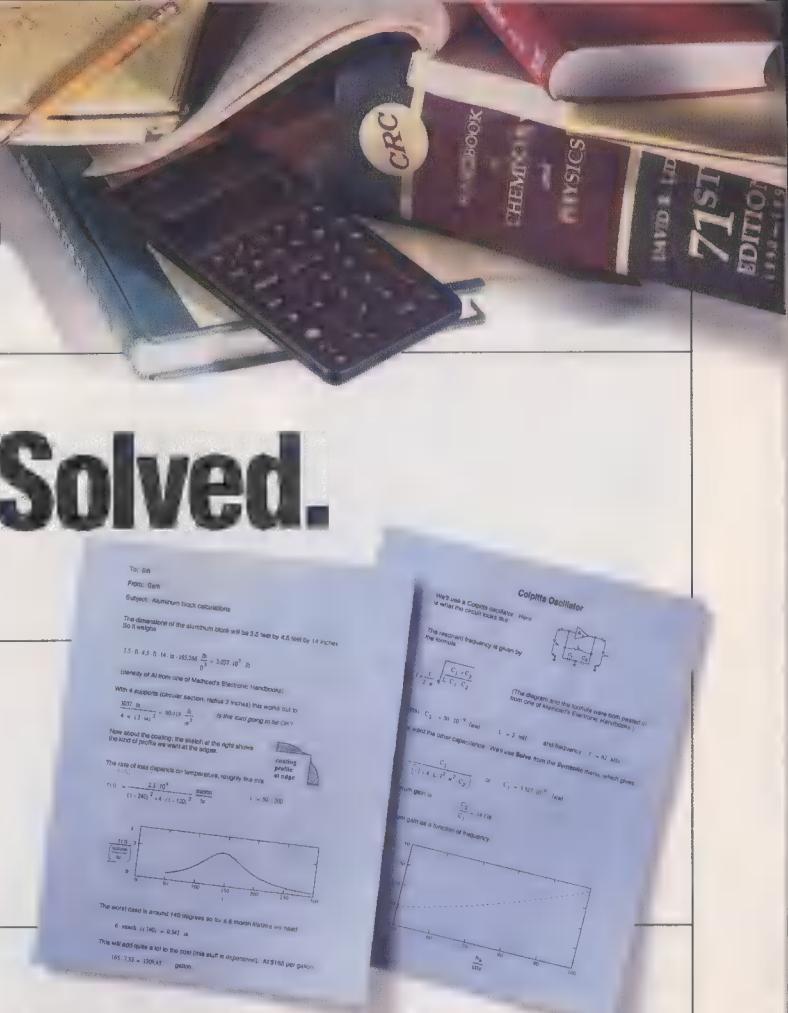
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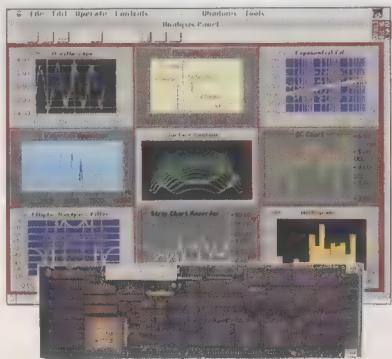
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Circle No. 13

Managing technology

Technological innovation needs radical strategies

If technological innovation is to occur at all these days, then conventional remedies (brainstorming, S-curve analysis, and so forth) are not sufficient. Consultant-author Tom Peters believes the odds against successful innovation have become so great that only radical strategies will make a difference. That is the message he will deliver in his fourth book, to be published later this year by Alfred A. Knopf Inc., New York City.

Tentatively titled *Beyond Hierarchy*, the book expands a strategy for innovation that Peters introduced in a two-part *California Management Review* series (Vol. 33, no. 1, Fall 1990, pp. 9-26 and Vol. 33, no. 2, pp. 9-23, Winter 1991).

Most important in Peters' approach to in-



TONY LEWIS/WI

novation is what he calls "violent market injection strategies." These strategies open a company up to "the winds of the market" in as many ways as possible so that you "trap yourself into having to innovate."

The strategies include licensing a firm's most advanced technology (as Sun Microsystems Inc. and a few others do) and obsoleting oneself by moving to market quickly with new services and products even though they may threaten the company's mainline businesses.

He also recommends selling cash cows while they still have market value (to force oneself to depend on newer lines of business) and requiring every department and division to demonstrate its competitive ability by selling its products and services outside the company. Conversely, units that are close to the market should be required to buy from the best possible source.

Additional tactics include making subcontracting a way of life (as MCI Communications Corp. does by purposely manufacturing nothing); and forming many alliances and

joint ventures—especially with overseas firms, start-ups, and one's own entrepreneurial employees. The remaining elements of Peters' strategy include: making proactive approaches to market innovation (joint development projects with leading customers, for example); measuring and rewarding innovative actions; organizing for innovation; and studying innovation.

Readers may obtain a sample of Peters' monthly newsletter, *On Achieving Excellence*, and information about his management seminars and training courses from the Tom Peters Group, 555 Hamilton Ave., Palo Alto, Calif. 94301.

Downside to diversity

Performance of some engineering teams is suffering because of the difficulties being experienced by and with ethnic minority and foreign-born staff, according to Edward Dunbar, a research psychologist at the University of California, Los Angeles.

Dunbar told *IEEE Spectrum* he is encountering concern at Southern California aerospace and defense firms because many ethnic minority and foreign-born engineers suspect that they are being excluded from the more challenging, high-visibility project teams. Also, they feel socially isolated at work from their engineering colleagues as well as from senior management, and they doubt that they are perceived as candidates for promotion to management. Some U.S.-born managers are also worried that Asians, in particular, lack the language and presentation skills necessary to be effective project team leaders.

The net effect is less commitment to their work groups as well as to their companies by ethnic minority and foreign-born engineers. Some have even talked of quitting. More often, the problem has stifled their ambitions for advancement.

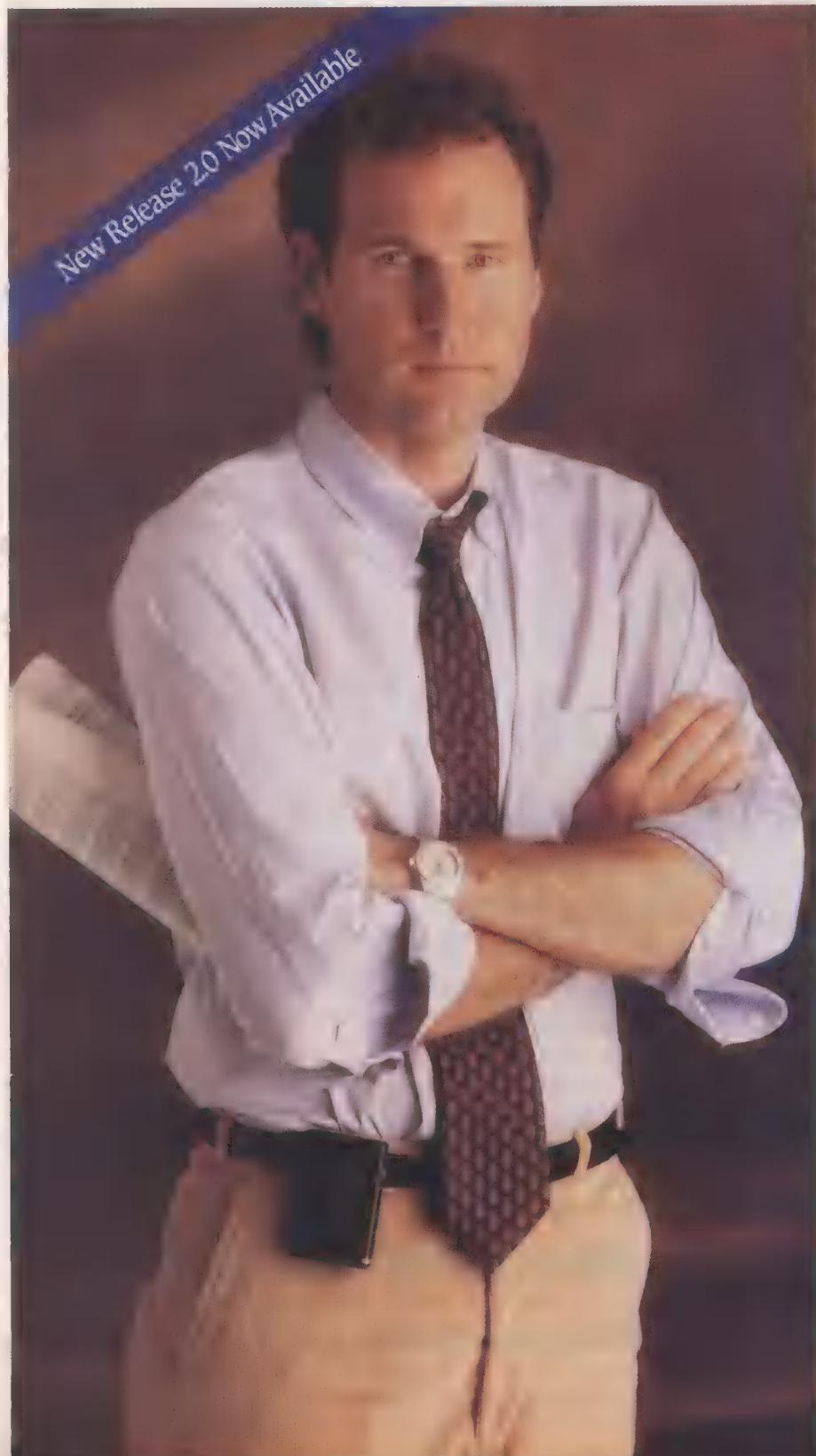
Dunbar says his surveys show that minorities are three times more likely than whites to feel excluded from informal work groups and they view their work units as significantly less efficient than do whites.

Dunbar recommends three actions: survey the organization to discover the extent of the problem; standardize procedures for communicating and participating in project teams by removing as many cultural barriers as possible; and target ethnic minorities and foreign-born employees for special attention and training in the skills needed to lead project teams.

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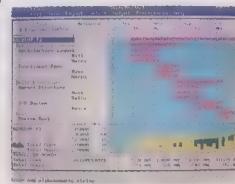


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Program notes

A union of superpowers

Consider this dilemma—you have use of two of the most powerful supercomputers available, but each is well suited for only part of the problem you need to solve. What do you do? Use both, of course.

Customarily, supercomputer users have turned to vector processors for high-speed number crunching. These machines send floating-point numbers through a pipeline so that several calculations are performed simultaneously. Recently, many people have decided this architecture is approaching its practical limit and that many parallel processors will be faster. And a massively parallel approach requires a problem to be split into many pieces that can be performed in parallel.

Gregory J. McRae, a professor at Carnegie Mellon University, Pittsburgh, and graduate student Robert Clay wrote a chemical process resource allocation program on a CM-2 Connection Machine from Thinking Machines Corp., Cambridge, Mass. They took advantage of the 32 768 processors in their CM-2 to calculate the minimum cost of assigning a large but finite number of resources to each of the thousands of tasks needed to run a sophisticated chemical plant.

But before the problem can be broken up, the cost of each individual resource must be calculated. The impossibility of coding this portion of the problem as a collection of independent or parallel tasks prevented McRae from taking full advantage of the CM-2's massive parallelism. So the job was recoded to run on a

Cray Y-MP, from which the intermediate answers were transferred to the CM-2 over a special bus at about 800 megabits per second. The bus was a High Performance Parallel Interface (Hippi)—its first practical use to link the two machines.

This method consumes one-tenth the total processing time of using the CM-2 alone, and the algorithms used have application in fields as diverse as DNA and protein sequence analysis, air pollution modeling, and molecular dynamics calculations.

After Ascii, Unicode

As international communications blossoms, so does the need for standard methods of expression. Currently, most computers resort to the Ascii standard to encode alphabetic characters. With a pattern of 8 bits, Ascii can easily represent letters in the English alphabet, upper- and lowercase, plus many punctuation marks and math symbols.

But languages other than English have presented so many conundrums that 12 computer companies, including IBM, Apple Computer, Sun Microsystems, and Microsoft, formed a consortium to devise a universal character code. They are calling the result Unicode.

Since Ascii can represent 256 unique characters it can accommodate several languages. The many other languages with more than 256 characters, however, present a much larger problem. To deal with them, the new Unicode employs 16 bits to encode each character, enabling it to define 65 536 different symbols.

Unicode can represent all the living languages in the world, plus classical Greek, according

(Continued on p. 77)

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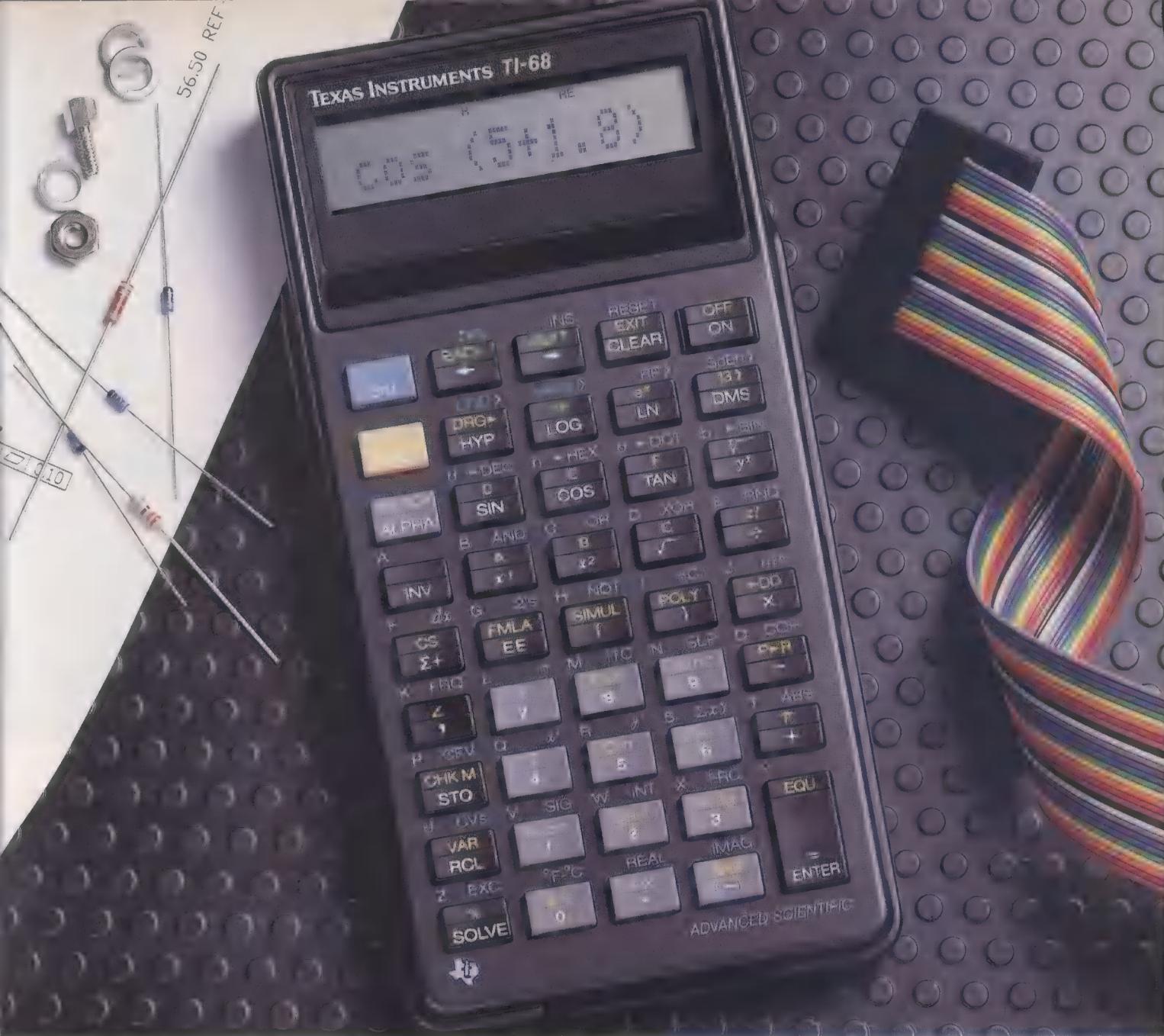
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TEXAS INSTRUMENTS

Forum

Magnetic stimulation and the nervous system

Of particular interest to me was the review of medical electronics [January 1990, p. 52], which gave a good overview of the leading edge of several fields in this area.

I was, however, somewhat taken aback by the section on magnetic stimulation and, in particular, the work which the National Institutes of Health have funded for the next three years at the Massachusetts Institute of Technology's Francis Bitter National Magnet Laboratory "to develop a device for stimulating hand and leg movement by application of a very intense magnetic field—about 17 teslas—to the brain." This would indeed be a considerable achievement with present commercially available magnetic stimulators having peak fields more on the order of 2 T. There will, nevertheless, be considerable concern over the possible adverse side effects of such intense fields, particularly with regard to the still somewhat tenuous link proposed between exposure to magnetic fields (usually over an extended period) and the induction of cancer.

My concern, as a biomedical engineer in the department of medical physics and bioengineering at Christchurch Hospital, is with regard to the claim made twice in this review that "such a technique may restore movement to paralyzed people." Such a claim, if it were true, would of course be of extraordinary significance to neurology and neurologic rehabilitation. However, I cannot see by what possible physiological mechanism one could restore movement to persons with paralysis or paresis by stimulation of the brain by whatever means.

Richard D. Jones
Christchurch, New Zealand

§ Reader Jones is essentially correct. The common forms of paralysis—resulting from spinal cord injury, certain cortical strokes, or demyelinating diseases—occur because nerve pathways from the brain are damaged. Magnetic brain stimulation could not restore movement through these damaged pathways. When there is partial spinal cord injury, the technique could provide a diagnostic indicator of residual capability. Though some have proposed that movement could be restored when paralysis is caused by dysfunction in certain parts of the brain, such as the parietal cortex, magnetic brain stimulation seems impractical for restoring movement to this small percentage of paralyzed people on a day-to-day basis. The prime applications of the technique will most likely be ensuring that nerve pathways remain intact during spinal surgery, diagnosing neurological malfunction, and neurological research.

—Ed.

Power yes, success no

The discussion of the Seabrook Nuclear plant [January, p. 64] caught my eye. The Atomic Safety and Licensing Board's recommendation for a full power license for that plant was highlighted as a "success."

An account in my local newspaper, however, states that the second largest electric utility in New Hampshire is "teetering on brink of bankruptcy." The bankrupt Public Service Company of New Hampshire is requesting a "182 percent increase in [the cost of] electricity sold by Public Service" to the New Hampshire Electric Cooperative.

Seabrook costs have caused the eastern Maine utilities to declare bankruptcy. Vermont Electric Co-op is bankrupt in fact if not in court; other co-ops are in a like state.

Do you wonder that we look upon the fate of the Shoreham plant as a success and the Seabrook licensing as an economic disaster for all who invested in it?

Roger Easton
Canaan, N.H.

The Oppenheimer case

The article "Origin of a culture" [March, p. 45] refers to the revocation of J. Robert Oppenheimer's security clearance in the context of the "hysteria of the times," saying that "The commission's decision was primarily based on his association with left-wing radicals."

I do not believe this to be correct.

The issue was dealt with at great length by a special board whose members (Gordon Gray, Ward Evans, and Thomas Morgan) were respected members of the academic or legal professions. The hearing lasted from April 12, 1954, through May 6, 1954. There is a 992-page transcript, *In the matter of J. Robert Oppenheimer*.

Oppenheimer was represented by three very able attorneys, was present throughout, and had no lack of supporting witnesses. There was no element of hysteria in the proceedings.

The crucial problem was that, while directing the atom bomb's development at Los Alamos, Oppenheimer had been sounded out by one Haakon Chevalier on the possibility of providing the Soviets with

technical information on the bomb through

■ British communist, George Eltenton. During a later investigation, Oppenheimer lied about his knowledge of Eltenton's efforts.

At page 137 of the transcript:
"A. I think I said little more than that Eltenton was somebody to worry about.

Q. Yes.
A. Then I was asked why did I say this. Then I invented a cock-and-bull story.
Q. Now let us go back to your interview with Colonel Pash. Did you tell him the truth about this thing?

A. No.
Q. You lied to him.
A. Yes."

So, while it is undeniably true that Oppenheimer's associations were instrumental in causing the investigation, the critical element in the adverse judgment of his character was proven falsehood.

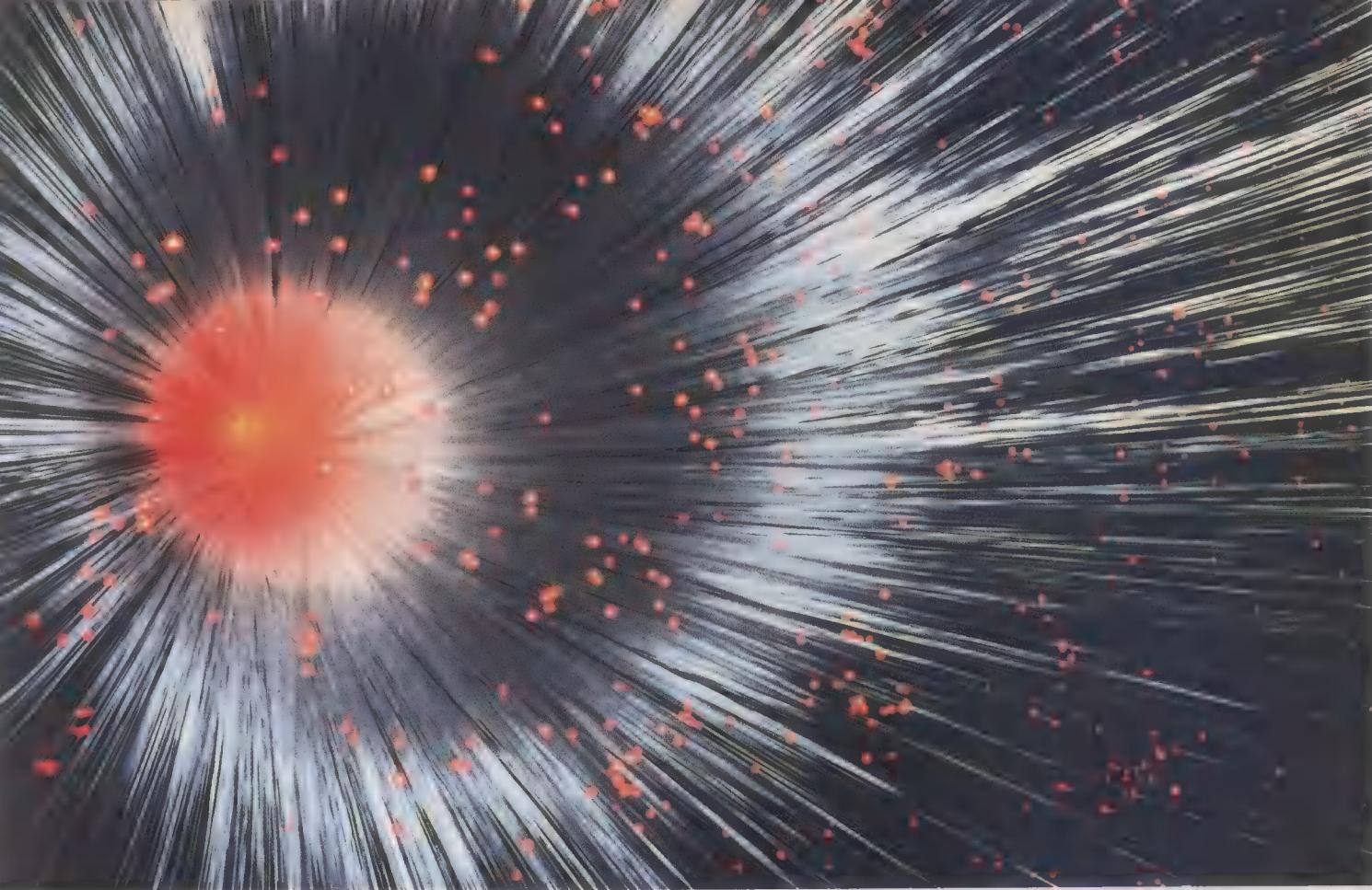
Stuart T. Martin
Burlington, Vt.

§ The Atomic Energy Commission's majority decision in the Oppenheimer case was based on "fundamental defects in character" and his "associations," according to the 1989 book *Atoms for Peace and War, 1953–1961* by Richard Hewlett and Jack Holl. The character defect alluded to charges of lying, and the Chevalier case was the Commission's prime evidence. But Hewlett and Holl questioned the validity of the character defect charge. Oppenheimer had alerted authorities to watch Eltenton on his own initiative, and when pressed, apparently lied to avoid divulging the name of Chevalier, a friend he believed was innocent. The authors suggest the charge may have been a front for the Commission's displeasure with his associations and his opposition to the hydrogen bomb development. —Ed.

Correction

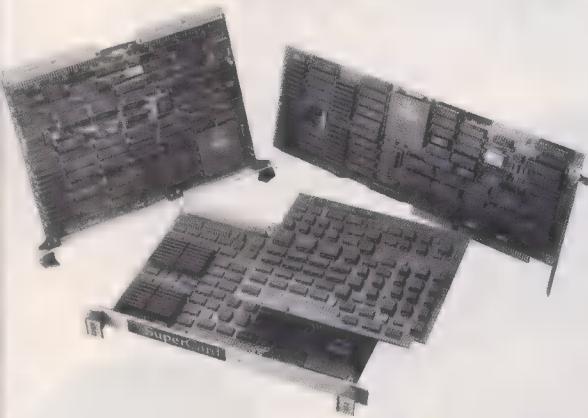
On p. 81 of the January issue, the location for Compaq Computer Corp. should have been Houston, Texas. —Ed.

Readers are invited to comment in this department on material previously published in *IEEE Spectrum*; on the policies and operations of the IEEE; and on technical, economic, or social matters of interest to the electrical and electronics engineering profession. Short, concise letters are preferred. The Editor reserves the right to limit debate on controversial issues. Contact Forum, *IEEE Spectrum*, 345 East 47th Street, New York, N.Y. 10017 U.S.A.



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IEEE SPECTRUM Volume 28 Number 6

Friendly second-sourcing

The Gulf war has brought home the issue of the U.S. military's dependence on foreign parts.

The basic questions are: is the foreign-made component of U.S. military equipment too high? Are the foreign parts used "commodity"-type parts, or are they cutting-edge, advanced-technology parts unavailable from U.S. suppliers?

Some observers on the Defense Science Board think the answer to the first question is yes. The board's 1988 report called the dependence on foreign parts dangerously high, and there's little reason not to expect similar warnings in the 1990 report, if and when it is made public.

Yet there are some good reasons why the percentage of foreign parts is so high. We need only recall the pressures to reduce the high costs of military procurement. In recent years the Department of Defense (DOD) has moved toward the use of off-the-shelf electronics, which can be as reliable as custom "military-grade" parts, or even more reliable, and orders of magnitude less expensive. The DOD's acceptance of a "form, fit, and function" policy, as opposed to the traditional "design to print" concept, resulted in military equipment that uses commercial, commodity-type electronic components.

By contrast, in the '50s and '60s, it was almost axiomatic that military contractors would produce their own state-of-the-art solid-state devices, at very high cost, to squeeze out the last measure of performance and reliability. Even routine components supplied from the outside (like Minuteman diodes) had individual serial numbers and pedigrees through which they could be traced back to their production lot and testing history.

In a form, fit, and function culture, however, procurement officials are probably unaware of the sources of many parts bought

by contractors, and may not be sensitive to how many purchased parts are foreign. Both the DOD and the General Accounting Office find it difficult to quantify the split.

Publications like the *Washington Post* and the newsweeklies have reported that urgent needs for replacement parts during the Gulf war were filled by other countries, like Japan, Germany, France, and Thailand.

Reporters were told that the State Department intervened with foreign governments in order to expedite certain parts to the Gulf.

A recent "60 Minutes" report included this commentary: ". . . without Japanese components for their radars, the pilots of our

Ironically, part of the reason for the DOD's recent emphasis on off-the-shelf equipment is so that stockpiles of spares can be minimized.

First, the Pentagon usually prefers spending for new weapons systems to warehousing spares or consumable parts. Then, too, the popular concept of just-in-time manufacture and "needs-pull" inventorying may play a role.

However, an active war that stresses, damages, or destroys equipment may change the rules. In wartime it would make sense for the military of any country to resist total dependence on parts from foreign countries, even nominal allies.

For example, as inventories of Maverick, TOW, Sparrow, and Sidewinder missiles are depleted, as they were in the Gulf, replacements would be easier if reliable, domestic sources of all parts were available.

This raises the second and more critical question. Would it even be realistic for the Defense Department to insist on alternate U.S. sources for all electronic components in military gear, or has the production capability needed to guarantee

such an "arsenal of democracy" moved irreversibly offshore?

Not yet addressed in the Gulf war post-mortem is the issue of captured enemy equipment, which might be easier to repair, maintain, and redeploy if it were either sold to the enemy by the United States in the first place or contained standard, interchangeable electronic components readily available from friendly countries. This may not have mattered in the Gulf conflict; reports indicate that most captured enemy equipment was intentionally destroyed.

Postwar studies by contractors' representatives as well as by the military itself should provide insight into these issues.

Donald Christiansen



Tony Leonardi

ASIAPOWER

*How Japan and the four tigers
are exploiting electrotechnology to create
a tripolar world economic structure
by the end of the decade*



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In Yokohama, Japan, a visitor hoping to ride a bullet train to Tokyo asks whether ■ Shinkansen is scheduled soon. "Oh, yes," comes the reply. "They run every half hour." The trip itself takes a half hour; by car it's about an hour.

In Singapore, a traveler meeting an executive in a cocktail lounge remarks on a cellular phone protruding from the latter's briefcase. "Everyone here carries a cellular," is the response. "We couldn't do business without one."

In Taipei, Taiwan, a foreigner marvels at the cornucopia of electronic products, from toys to computers, displayed in hundreds of booths around the spacious atrium of the World Trade Center. Outside Seoul, South Korea, he is intrigued by the energy of hordes of hikers on white-capped Mount Pukhan on a Sunday afternoon—their only day off. And in Hong Kong, he is bedazzled by a modernistic waterfront Science Museum jammed with young people.

Again and again across the vast distances of Asia's Pacific Rim, such experiences pile up. The area's five most dynamic nations are Japan and the four "little tigers," as South Korea, Taiwan, Hong Kong, and Singapore are known. Their capitals' extensive expressways, sleek subways, and glass-sheathed skyscrapers seem to thrust sharply into the future. It is a future synonymous with electrotechnology. For in large part, electrotechnology—consumer electronics, computers, computerized design and manufacturing, and the satellite and optical-fiber links of a global economy—has fired their ascent.

That ascent has been spectacular. Over two decades, according to the World Bank, these five nations have increased their gross national product (GNP) at double to triple the rates of most older industrialized nations. By the year 2000, *Fortune* magazine has projected, the entire Asian Pacific Rim, despite including some of the world's poorest nations, will have a share of world gross economic product exceeding that of the European Community (EC) and equal to North America's; by 2020, it may have double the EC's wealth.

Indeed, some in the media have speculated that soon Japan alone may possess the momentum to surpass the United States economically and technologically. Not so, said ■ Pentagon Future Security Environment Working Group

Alfred Balk Issue Editor

in 1988. Japan has half the U.S. population and GNP. Factoring in these and other advantages such as university and science quality, military power, and business reach (one-fifth of U.S. corporate assets lie outside U.S. borders), it projected that, in 2010 as now, U.S. GNP will be twice Japan's. But even raising the question indicates the magnitude of the changes now occurring.

Historically, technology has been an Asian forte. China, for example, is credited with having invented gunpowder and paper. When Marco Polo's father visited Kublai Khan in the 13th century, the Mongol prince's main request was for 100 Europeans learned in science and the arts.

That longing for knowledge persists. Combined with the Confucian ethic of toil, respect for authority, and pre-

ference for cooperation over confrontation, it has inspired achievements far out of proportion to the populations of the achieving nations.

Japan is only one example. South Korea's population is half that of Japan; Taiwan's, half of Korea's; and Singapore's, half of Hong Kong's. Yet all are export powers. Beyond these, less industrialized Asian nations nicknamed "tiger cubs" have demonstrated technological and business capacities.

All these nations toil in the shadow of two reawakening giants, China and India. The world's most populous nations, both have scored impressively in technologies ranging from aerospace to computers. India builds nuclear plants, communications satellites, and missile launchers. So does China, which, in spite of chronic political turmoil, ranks

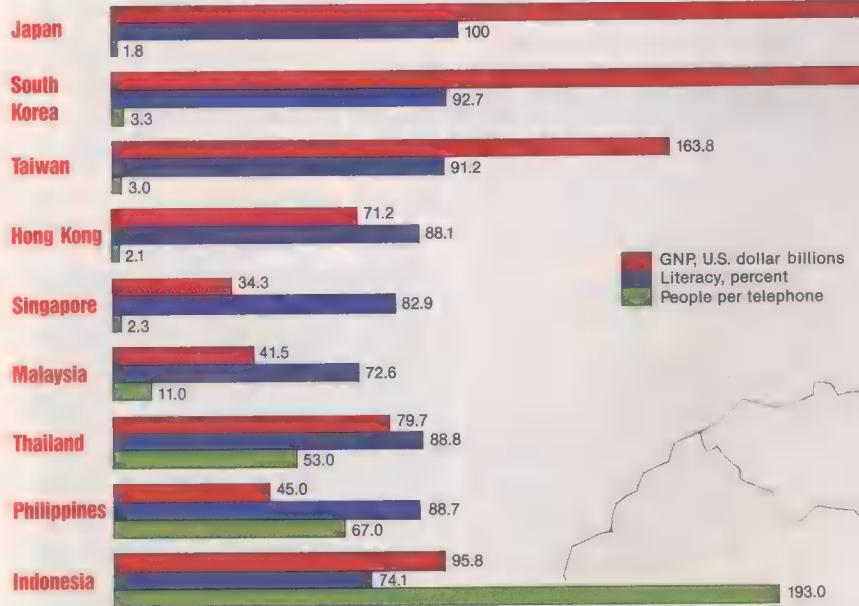
fifth among all world arms exporters.

Still, China's strongest technological impact for now may be due to its expatriates: the millions of overseas Chinese who energize the science, technology, and other establishments in North America and East Asia.

What is the technological profile of this Pacific Rim power center? How did it evolve? Where are new investment and technology alliances centered? What is its future?

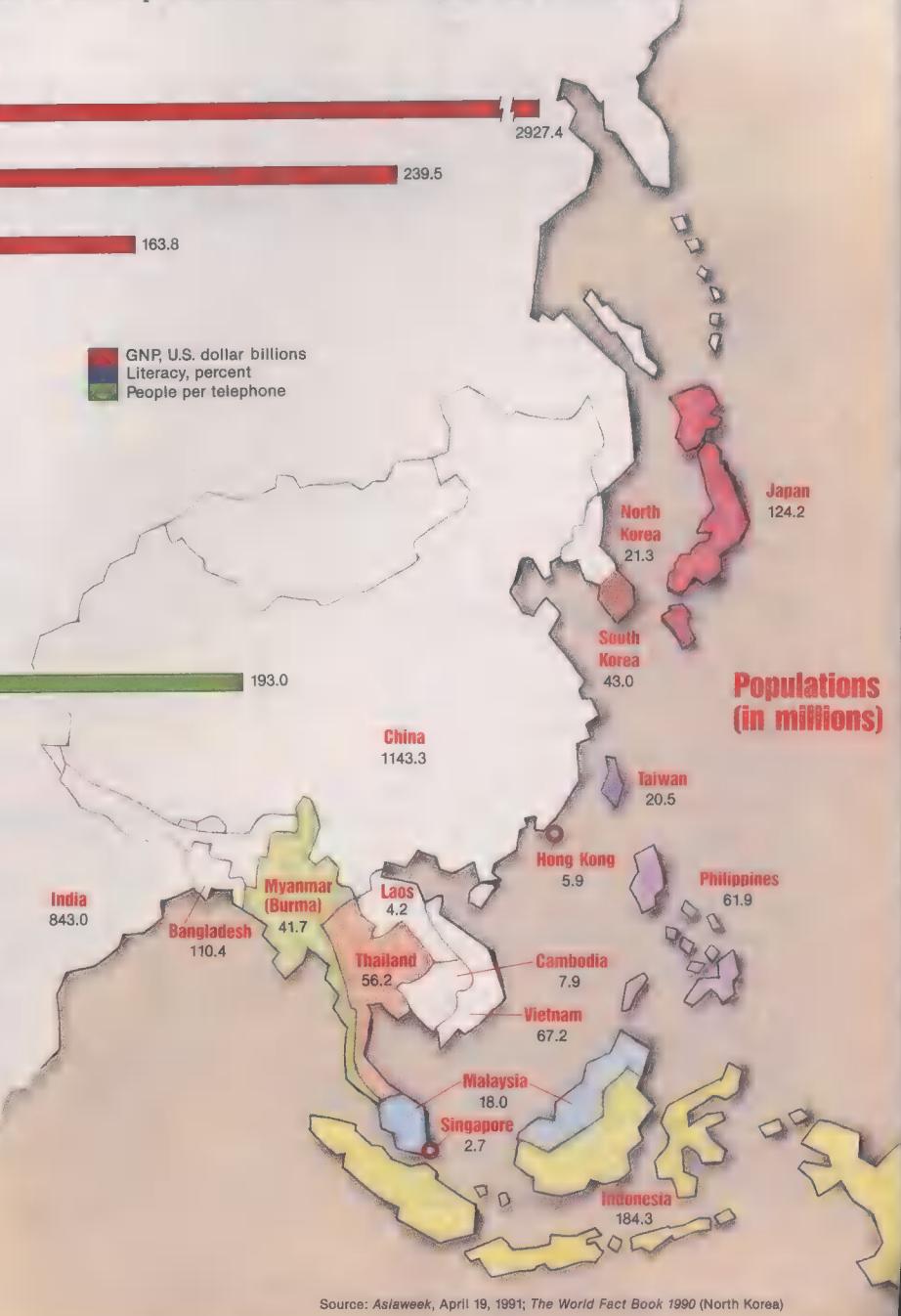
Last June, in "Europower '92," *IEEE Spectrum* reported on the "new Europe" evolving within a historic European Community single-market structure. In this issue, we focus on the five-nation heart of East Asia's power crescent and its implications for other regions and other Asian nations in the Pacific Rim's vibrant future. ♦

Asia's power crescent in profile



Source: *Asiaweek*, April 19, 1991

*Asia includes the world's two most populous nations, China and India [map, right]; but Japan has the region's largest economy—second only to that of the United States—and its highest per-capita GNP (US \$23,570). Among the other power crescent nations [bar chart, above], the four newly industrialized tigers follow in per-capita income: Singapore (\$12,718), Hong Kong (\$12,069), Taiwan (\$7,990), and South Korea (\$5,569). In the next echelon, the newly industrializing tiger cubs, the order is Malaysia (\$2,305), Thailand (\$1,418), the Philippines (\$727), and Indonesia (\$520). (All data from *Asiaweek*, April 19, 1991.)*



East Asia's power crescent

Fierce competition among an immense region's advanced and emerging industrialized economies is intensifying the world's Pacific tilt

It is the year 2000. Japan's Ministry of International Trade and Industry (MITI) has orchestrated the multinational development of an engine that will enable a jetliner to cruise at 3000 mph. To be completed in

2020, the plane, also multinational, will bring Tokyo within 3½ hours of New York City or European commercial centers. The feat will tip the world's Pacific tilt yet another degree.

That tilt has progressed by degrees in every decade since World War II. In the '40s and '50s Japan repaired wartime damage while longtime Asian colonies won their independence. In the '60s and '70s a wave of export-driven industrialization released an Asian export flood that crossed watershed in 1983: for the first time goods flowing over the Pacific Ocean exceeded in value those passing over the Atlantic.

The '80s brought other watersheds. In 1984 air traffic controllers recorded more jumbo jets aloft over the Pacific than the Atlantic. By 1990 two Asian nations, Japan and Taiwan, led the world in non-gold foreign reserves, with some US \$70 billion each. By this decade's end, it is projected that Asia's gross economic product will surpass Western Europe's and about equal North America's.

Already, the region has had a resounding impact on global markets and industries, notably auto-making and electronics. In the '80s it also began to make its weight felt as both an investor [tables at right and bottom opposite] and an enhanced target of investment [top left and center tables

opposite]. In the global economy of the '90s these trends are likely to be sustained, with heavier emphasis on power crescent nations' investment in one another.

The Pacific tilt also applies to technology. As it and business, communications, and entertainment become globalized along with economies, this technological tilt increasingly is challenging national and corporate strategies [“Competing in a global economy,” *IEEE Spectrum*, April 1990, pp. 20–24; “Industries transcend national boundaries,” September 1990, pp. 26–31]. Not the least challenged are the prime movers of this change themselves—the business, technological, and governmental establishments of Asia's new Pacific Rim powers. For the tides

they have unleashed sweep over them, too, requiring constant adjustment.

How have Japan and the four tigers wrought their economical and technological “miracle”? How has it affected them and their Asian neighbors? How might it further reconfigure the region's economic and technological profiles?

JAPAN'S ASCENT. These Pacific Rim phenomena have deep roots. Centuries ago China led in technological creativity, and before and during World War II Japan was an industrial power ruling an empire that extended from China through Korea, Taiwan, and eventually much of Southeast Asia to Singapore. Its mammoth *zaibatsu* trusts—

since split up into still powerful conglomerates—ran a vigorous economy.

In fact, Harvard University's John K. Fairbank and two colleagues noted in their study *East Asia: Tradition and Transformation* (Houghton Mifflin, Boston, revised 1989 edition), that at the war's outbreak, technologically “Japan had an edge with its superior Zero fighter planes and long-distance torpedoes.... But America then pulled ahead, developing new planes, radar, homing torpedoes, proximity fuses, new medicines, and eventually the atomic bomb.”

Michiyuki Uenohara, executive adviser at NEC Corp. and a Japanese military pilot during World War II, recalls this asymmetry and how it later helped motivate him in creating a NEC research staff of more than 10 000 engineers. “I remember feeling frustrated and humiliated that our electronics always seemed inferior,” he told *IEEE Spectrum*. “I determined that, if I ever got the chance, I would make any technology I was involved with the best.”

Japan's defeat nurtured the seeds of its success. Under post-war U.S. military occupation, the country adopted a new constitution and introduced land redistribution, antitrust reforms, and a ceiling on military budgets—1 percent of its gross national product (GNP). It also encouraged high savings and discouraged credit buying in order to foster investment. In 1947, when Japan adopt-

Top 20 motor vehicle manufacturers

Company and country	1989 total	Pasenger cars	Commercial vehicles
1. General Motors Corp., United States	7 611 477	5 545 869	2 065 578
2. Ford Motor Co., United States	6 046 514	4 056 726	1 989 788
3. Toyota Motor Corp., Japan	4 278 190	3 352 628	925 582
4. Nissan Motor Co., Japan	3 003 481	2 252 607	750 854
5. Volkswagen AG, West Germany	2 880 892	2 753 715	127 177
6. Peugeot-Citroen, France	2 687 893	2 433 403	254 490
7. Chrysler Corp., United States	2 208 629	1 052 504	1 156 125
8. Renault, France	2 204 915	1 850 023	354 892
9. Fiat SpA, Italy	2 157 827	1 875 415	282 412
10. Honda Motor Co., Japan	1 811 962	1 604 430	207 532
11. Mazda Motor Corp., Japan	1 486 586	1 184 166	302 420
12. Mitsubishi Motors Corp., Japan	1 249 510	708 418	541 092
13. Suzuki Motor Co., Japan	868 318	430 053	438 265
14. Daimler-Benz AG, West Germany	783 215	536 993	246 222
15. Vaz, USSR	733 200	733 200	0
16. Daihatsu Motor Co. ¹ , Japan	664 239	263 631	400 608
17. Hyundai Corp., South Korea	614 379	525 857	88 522
18. Fuji-Subaru ² , Japan	556 590	310 623	245 967
19. Isuzu Motors Ltd., Japan	556 463	188 725	367 738
20. Rover Group, UK	538 769	468 619	69 150

¹ Member of Toyota group. ² Affiliated with Nissan Motor.

Source: Motor Vehicle Manufacturers Association of the United States Inc.

ed its constitution, production was barely over one-third its prewar level. By 1975 the country had succeeded so well in its exported strategy that it trailed only the United States and the Soviet Union in GNP.

Still, one of Fairbank's colleagues pointed out, it was a swelling domestic market, not just trade, that was "critical in creating the economies of scale that made Japan so formidable a competitor abroad. As a percent of GNP, Japan's exports were less than those of England, France, or West Germany." This domestic success, he added, was deftly ensured by "the combination of free enterprise and government guidance...labeled Japan, Inc."

Foreign direct investment in Japan,* in U.S. dollar millions

Country or region	1985	Cumulative fiscal year 1985-89
United States	385	6288
Canada	13	152
Europe	334	3013
West Germany	23	546
Netherlands	47	482
Switzerland	68	928
United Kingdom	58	518

*These flow figures are collected on an approval or notification basis and are not strictly comparable to balance-of-payments data. Divergence exists between the methods used to measure inward and outward investment. Reinvestment to acquire equity is generally included.

Source: Japanese Ministry of Finance as reprinted in *International Direct Investment and the New Economic Environment: The Tokyo Roundtable*, OECD, 1989



Asia-Pacific investment in 'tiger cubs,' in U.S. dollar millions

From	Malaysia ¹		Indonesia ²		Thailand ³		Philippines ⁴	
	1989	Change from '88	1989	Change from '88	1989	Change from '88	1989	Change from '88
Japan	996	121%	769	240%	3251	15%	157	65%
South Korea	70	367%	466	123%	171	57%	18	800%
Taiwan	800	161%	158	-83%	867	2%	148	36%
Singapore	338	118%	166	-35%	407	48%	24	1100%
Hong Kong	130	17%	407	75%	561	26%	132	388%
World total	3205	78%	4719	7%	7979	28%	800	77%

1 Foreign investment flow (foreign equity and loan attributed to foreign interest) in manufacturing projects approved by the Malaysian Industrial Development Authority.

2 Total foreign capital in projects approved by BKPM—The National Investment Coordinating Board.

3 Applications for foreign investment approved by the country's Board of Investment.

4 Inward investment approved by the country's Board of Investment.

Source: Merrill Lynch

U.S. technology transfers, bought for an estimated US \$10 billion, also played a role, as did reverse engineering. The transfers included transistor patents (licensed by Western Electric Co. in the mid-'50s); semiconductor technology (Fairchild Industries Inc., 1963); and IC technology (Texas Instruments Inc., 1968). With such building blocks in place, MITI in the early 1970s condoned the lowering of some semiconductor import barriers—impelling greater Japanese IC manufacturing competitiveness and nudging the country's companies toward higher-value-added, more knowledge-intensive fields ("How government helps: MITI and its clones," p. 53).

Foreign direct investment in the four tigers*

Country or region	US dollar millions
South Korea to February 1991	
United States	317.5
Japan	235.8
Germany	62.3
England	45.8
Netherlands	36.3
Total	802.5
Taiwan, 1989	
United States	343.0
Japan	640.6
Europe	531.4
Hong Kong, 1988	
United States	1141
Japan	892
South Korea	N.A. ¹
Singapore	46
Taiwan	23
Europe (aggregate)	462.7
Singapore, 1989	
United States	4020
Japan	3270
Europe	3420

*Figures are derived from different sources and may not be directly comparable.

¹ Not available

Sources: Korea Government offices; China External Development Council; Business International Forecasting Services (Hong Kong); Singapore Economic Development Board

Marketing prowess in electrotechnology, automobiles, and other lucrative fields then vaulted Japan past the more populous Soviet Union in GNP and onto the start of the Pacific Rim power crescent. That crescent [see map, p. 25] encompasses the four "little dragons" or tigers—South Korea, Taiwan, Hong Kong, and Singapore—plus such "tiger cubs" as Malaysia, Thailand, and Indonesia, which are jockeying to move onto the value-added industrialization ladder.

Those hoping to ascend that ladder have four rungs to climb: components production; full-scale manufacturing and assembly; indigenous high-technology research and development; and a diverse scientific research

Japanese direct investment abroad,* in U.S. dollar millions

Country or region	1985	Cumulative, fiscal year 1985-89
United States	5395	71 860
Canada	100	3 231
Europe	1930	30 164
West Germany	172	2 364
Netherlands	613	5 525
United Kingdom	375	10 554
Latin America, including offshore banking	2616	31 617
Middle East, including OPEC	45	3 388
Asia	1435	32 227
Africa	172	4 604

*These flow figures are collected on an approval or notification basis and are not strictly comparable to balance-of-payments data. Divergence exists between the methods used to measure inward and outward investment. Reinvestment to acquire equity is generally included.

Source: Japanese Ministry of Finance as reprinted in *International Direct Investment and the New Economic Environment: The Tokyo Roundtable*, OECD, 1989

A year's investment abroad: by Taiwan

Country or region	US \$ millions
Japan	1.8
Hong Kong	33.1
Singapore	47.6
Indonesia	61.9
Malaysia	184.9
Philippines	123.6
Thailand	149.4
United States	428.7
Europe	265.9
Total (world)	1552.2

Sources: Investment Commission, Ministry of Economic Affairs (for 1990)

by South Korea

Region	US \$ millions
Southeast Asia	309.4
North America	482.0
Europe	92.4
Total (world)	1019.7

Source: Korean Government sources (year through February 1991)

capability. Only the United States and several European Community nations have scaled all four rungs. But Japan stands high on the third, and MITI has charted an assault on the fourth, predicated on an Asian production and marketing base in its backyard [again, "How government helps," p. 53].

Leading Japanese firms, including electronics and auto producers, also are deploying to other hemispheres. In this globalization, data from the Organization for Economic Cooperation and Development (OECD) and the World Bank show the United States and the European Community leading substantially. But tendencies toward cross-border cooperation and investment and the convergence of industrialized nations' capabilities are becoming steadily more apparent.

SOUTH KOREA'S BOOM. Meanwhile, westward across the Sea of Japan, South Korea also has boomed. Though its 1960 GNP compared with that of such poor nations as Ghana, its GNP growth in most years since has averaged 8 per cent. People's life expectancy has risen by eight months annually; literacy is over 90 per cent; and a previously authoritarian government has steadily democratized. With a per-capita GNP of US \$5569, the country now claims Asia-Pacific's largest middle class outside Japan.

Among the four Asian tigers, Korea's economic management probably most closely resembles Japan's. Like Japan, whose colony it was from 1910 to 1945, South Korea possessed several little-recognized prerequisites for success. These included a colonial infrastructure of roads, communications, and education, plus manufacturing experience. Onto these were grafted a comparable work ethic, vertically integrated conglomerates (called *chaebols*), industrial planning agencies akin to MITI, rigid import barriers, and the exploitation of an open U.S. market for exports.

From the first rung on industrialization's ladder, where it served as an outsourcing base for Japanese, U.S., and European component manufacturing, South Korea moved up to steel, shipbuilding, and auto production, and then to simple electronic products. More recently, through joint ventures and indigenous R&D spurred by its Ministry of Trade and Industry (MTI), it has ventured into more advanced electrotechnology, including aerospace, very large-scale integration (VLSI), and industrial robots.

TAIWAN'S TURNAROUND. South of Korea and Japan, on an island less than 100 km from mainland China, Taiwan has achieved another spectacular success. Also a Japanese colony for decades, Taiwan reverted briefly to postwar Chinese jurisdiction, but with the arrival of 2 million Chinese Nationalists fleeing the newly Communist mainland in 1949, became a rival claimant to power.

The island's GNP then also compared to Ghana's. But privatization of state industries plus a succession of four-year plans paved

the road to industrial development. By the '60s the twin magnets of cheap labor and financial incentives attracted sufficient outside capital for an economic takeoff. Free compulsory education, introduced in 1968, raised literacy to over 90 per cent; life expectancy rose to European and U.S. levels; and the island's economy progressed up the value-added ladder from labor- and capital-intensive ventures such as steelmaking to the complexities of autos, military equipment, and computers.

By last fall Taiwan ranked as the world's 13th largest trading nation and held non-gold foreign reserves—some US \$74 billion—at least temporarily surpassing Japan's. Its previously clandestine trade with China through Hong Kong—over US \$2 billion annually—is now open, and its overseas investment for 1990 totaled US \$15.5 billion.

Asia's other two tigers are micro-states at the tips of strategic peninsulas: Singapore, at the base of peninsular Malaysia, and Hong Kong, next door to China. Both were 19th century pillars of Britain's empire that found different paths to prosperity.

THE MICRO-STATE TIGERS. Singapore, with only 2.7 million people—three-fourths of them overseas Chinese—became self-governing in 1959. It briefly joined the Federation of Malaysia, then became fully independent in 1965 and parlayed strategic port, shipbuilding, and oil-refining facilities into a diverse economy with per-capita income second in Asia only to Japan.

Under autocratic but venerated Prime Minister Lee Kuan Yew, this almost uniquely

of them Chinese, the territory has expanded its electronics and other exports by a standard script. That is, once export markets are established, as local wages rise, manufacturers stay competitive by moving at least some production to lower-wage areas.

In Hong Kong, the movement is mainly across the Chinese border, to Guangdong. There, in one of several economic zones established by China, electronics accounts for more than 40 per cent of some US \$1.3 billion annual output. Virtually all is tied to Hong Kong.

ENTER THE CUBS. Trailing just one stage behind the four tigers are at least three tiger cubs. These are Malaysia, Thailand, and Indonesia. None is yet advanced enough for economic takeoff, but all are alluring enough to industries and investors to have reached development's first rung.

Malaysia, for example, last year attracted some US \$2.3 billion in manufacturing investment from Taiwan and US \$1.5 billion from Japan. It is the world's No. 3 producer, and No. 1 exporter, of semiconductor chips, with an electronics sector employing about 100 000 workers.

Since the early '70s, when Government incentives attracted a procession of companies, Malaysia's semiconductor devices sector alone has grown by some 20 percent annually. But its largest single industrial venture is its Proton auto manufacturer, approximately one-third owned by Mitsubishi Motors Corp. of Japan.

In Thailand, Japan provided about half of the country's US \$8 billion in foreign invest-

ment in 1989, and Japanese automakers there are even more active than in Malaysia. One reason is Thailand's own auto market, estimated at 300 000 vehicles last year. Among others, Toyota Motor Corp. operates a major plant in Bangkok, and Mitsubishi has a joint venture called MMC Sittipol, whose market includes Canada. Labor-intensive semiconductor production has also become a mainstay.

Indonesia's new technology activities have been concentrated in its Batam island area, near Singapore. Encompassed in Singapore's "growth triangle" strategy, along with the Malaysian state of Johore, Batam's population of some 100 000 inhabits an area two-thirds the size of Singapore. But it already has attracted a Singapore subsidiary of Sumitomo Corp., among others.

Some analysts see two other small nations as on the threshold of tiger cubhood. These are Vietnam and the Philippines.

"Farsighted people see a real future in Vietnam, if the embargo against it is lifted," David L. Brodess, senior consultant for Business International in Hong Kong told *Spectrum*. "Its people are well educated, they have a taste for Western goods, and they're experienced traders."

The Philippines, meanwhile, are seen by some as offering more immediate potential. "Given the availability of trained English-

By 1984, air traffic controllers were reporting more jumbo jets aloft over the Pacific than the Atlantic

clean, corruption-free, development-minded island attracted the offshore manufacturing operations of leading computer, telecommunications, and other electronics companies.

Plowing back revenues into education and physical infrastructure, it methodically progressed to the point that a new administration, installed last fall, not only is nurturing indigenous R&D facilities, but is also routing investment by Singapore-based companies into Malaysia and Indonesia, whose low labor costs offer the offshore production advantages it once provided.

Hong Kong, on the other hand, has remained the epitome of a laissez-faire entrepreneurial haven. It exploits its status as Southeast Asia's financial capital and an economic back door to China—to whose jurisdiction a treaty will return it in 1997. At US \$12 069, its GNP per capita is on a par with Singapore's and is 37 times that of China. With less than 6 million people, nearly all



Toyotas awaiting export from Nagoya, Japan, symbolize the tidal wave of Japanese autos that has swept over the world since 1960, when all Japanese firms produced only 481,500 vehicles. Last year's Japanese total, according to the Motor Vehicle Manufacturers Association, was 14.56 million—1.9 million more than companies in Western Europe and just 1.4 million fewer than those in North America. East Asia nations now are assembly as well as outsourcing bases for several Japanese firms.

speaking engineers," consultant S. Thomas Moser said in an analysis for his company, KPMG High Technology Practice of Chicago, "the Philippines are perhaps best equipped of all the newly industrializing economies to assimilate this technology." But political instability has deterred multinationals from new investment there.

Beyond the present power crescent, Australia and New Zealand in the Southern Hemisphere and the two giants of Asia—India and China—also must be factored into any future Asiapower equation, adding to its potential power—and problems.

FUTURE CLOUDS. Many of the region's problems are severe. One is poverty: some of the poorest large nations in the world are Asian—notably China, India, and Indonesia [see figure, p. 25]. Related is uncontrolled population growth. Among Asian nations, only Japan and the four tigers have managed to stabilize population, both a cause and result of successful industrialization.

Political instability also is still a specter, haunting nations ranging from gigantic China to smaller societies such as Cambodia and the Philippines. "Investors simply do not look twice at any nation where their investments may be in jeopardy," one financial analyst in the region told *Spectrum*. "There's no shortage of other options."

Indeed, it is the ripple effect of regional cross-investment that accelerates the spread of economic, political, and technological development. Once a fast-growing economy seeks to expand its base, as Japan and fel-

low Pacific Rim investors have shown, nothing is more inviting than to sink new roots in nearby developing nations, first for outsourcing, then for other steps up the industrialization ladder.

Still another problem is regional rivalries. China and Japan in particular are historic big-power adversaries, as are China and India. Memories of Japan's colonial and wartime occupation years scar its relations with almost every other East Asian nation. In Seoul, in fact, in contrast to other tigers' capitals, one cannot help being struck by the paucity of Japanese autos, consumer electronic products, and businessmen from Tokyo or other Japanese commercial centers. Both the asymmetrical Japanese economic and technological weight in the region and growing market saturation in industries such as autos and consumer electronics suggest that European-type intra-regional strains lie ahead.

REGIONAL TIES. But it is the technopolis of the present crescent that will most determine the region's economic profile in 2000. By then, some authorities foresee several tigers being admitted to the OECD, the elite club of 24 industrialized nations, whose only Asian member is Japan. South Korea, for one, already has announced its intention to nearly double per-capita income and be admitted to the OECD by 1996.

Some type of expanded regional organization also is predicted. One scenario, recently proposed by Malaysia, is to enlarge the Association of Southeast Asian Nations

(Asean). Its present members are Indonesia, Malaysia, Singapore, Thailand, the Philippines, and Brunei. Added would be Japan, China, South Korea, Taiwan, Hong Kong, and possibly Vietnam, Cambodia, and Laos.

Should the sputtering negotiations over trade reforms in the General Agreement on Tariffs and Trade (GATT) break down, some economists suggest, such a grouping then could become part of a tripolar bloc system that would also include the European Community and an evolving North and South American zone. Japan, however, is loath to join any Asian regional body that omits the United States and Australia.

"Japan needs U.S. cooperation, and we wonder if it's wise to exclude such countries," explained Yutaka Kosai, president of the Japan Center for Economic Research. He added that "diversity in stages of development, income gaps, and very different political histories" dim any likelihood of a counterpart of the European Community. Further, he pointed out, "Inter-regional trade with Europe and North America is growing faster than intra-regional trade" [see table below].

Clearly, no pan-Asian organization could succeed without Japan. Its economic and technological influence now permeates the region through its products, its investments—some US \$10 billion in the five leading Southeast Asian economies in two years—and its citizens' presence. More than 80,000 Japanese now live in the region's six major economies, and visiting Japanese

World trade by region*

	1979	1989
Asia ↔ North America	6.4%	11.9%
Asia → West Europe	5.0%	7.6%
Within Asia	6.3%	10.0%
North America ↔ West Europe	6.6%	7.3%
North America — Latin America	4.0%	3.6%
Within North America	4.6%	5.3%
Within West Europe	28.0%	31.1%
Other	39.1%	23.2%

*Total trade in 1979 was US \$2.2 trillion; in 1989, US \$3.1 trillion.
Source: General Agreement on Tariffs and Trade, as cited in *Far Eastern Economic Review*, Jan. 31, 1991

businessmen and new Japanese-language schools are conspicuous in all the tigers but South Korea, where relations remain cool.

At the same time, Japanese corporate leaders are wary of the tigers. Reporting on a comprehensive 1989 survey it did, Tokyo's leading financial daily, *Nihon Keizai Shimbun*, said that the tigers are viewed by executives as "a major threat" to the Japanese. South Korea was perceived as probably "Japan's strongest Asian business rival in the next decade, along with China," the report added, while "the other newly industrializing economies—Taiwan, Singapore, and Hong Kong—will be increasingly fierce competitors."

Poised for technological leadership

Communications and computers are advancing rapidly in the wake of East Asia's success in consumer electronics

A

cknowledged leaders in such technologies as consumer electronics, microelectronics, and computer assembly, East Asian nations are striving to adjust their strategies to a changing market. Increasingly,

they look to new technologies to give them a competitive edge. Japan has ambitious plans in aerospace, for example, while South Korea aims to become a leader in industrial automation products. Singapore and Hong Kong, no longer content simply to fabricate or package ICs, are improving their design skills.

CONSUMERS: deciding where and how to make what

Ronald K. Jurgen Senior Editor

Game plans are changing in the East Asian consumer electronics arena as the key players try to cope with such problems as slackening competitiveness caused by the strengthening of their currency and rising labor costs. Among other concerns are a weak economic outlook in the United States and many European nations as well as a maturing of worldwide markets for traditional products like television sets, videocassette recorders, and microwave ovens.

At home Japan is cutting back its investment in plants and equipment, but it is expanding operations in North America and the European Community and increasing efforts to develop unique products for domestic and foreign markets.

South Korea, Hong Kong, and Taiwan are moving into production of high-value-added products, leaving the low end of the market to Malaysia and Thailand. While also shifting many manufacturing operations to China and Southeast Asia, these three nations are also pushing R&D to diminish their dependence on Japanese know-how.

The major consumer electronics manufacturers in Japan are Matsushita Electric Industrial (the largest), Sony, Toshiba, Hitachi, NEC, Sharp, Pioneer Electronics, Mitsubishi Electric, Fujitsu General, Sanyo Electric, and Victor Company of Japan Ltd.

According to estimates from the Electronic Industries Association of Japan (EIA), the country last year exported nearly 26 million videotape recorders, 7 million camcorders, 4 million color TV sets, and 11 million compact-disc players. Total 1990 consumer electronic equipment produced was estimated to have a factory value of 4.35 trillion yen (US \$32 billion), an increase of 3.8 percent over 1989.

But the domestic market for consumer electronic products weakened with sluggish demand for videotape recorders, compact-disc recorders, and hi-fi audio systems.

STILL KING OF THE HILL. Despite the slowdown, Japan remains the unchallenged king worldwide in consumer electronics. It has most of the world's leading companies in the field, achieving that top rank mainly by continuously introducing innovative products. Last year, for example, several Japanese companies unveiled high-definition television (HDTV) products, even though there is only 1 hour of satellite broadcasting of HDTV programming per day. But HDTV is not expected to make an impact on the ordinary Japanese consumer very soon. Youkichi Suzuki of Japan's Ministry of International Trade and Industry told *IEEE Spectrum* in Japan that "even in 2000, there will be only a small market for HDTV."

Among other advanced consumer electronic products that Japanese firms have introduced domestically in recent years are those incorporating fuzzy logic and neural networks. (Fuzzy logic is a branch of logic that uses degrees of membership in sets rather than a strict either-or membership. A neural network consists of many densely interlinked processing elements that keep adjusting their outputs till the net result represents the input.) Matsushita has marketed heat-pump room air conditioners, vacuum cleaners, and washing machines that use neural-network and fuzzy-logic technology.

Another Japanese innovation is a satellite network of 18 digital pay-to-listen FM radio stations that offer "relaxing" music, mostly from the United States, and natural sound recordings, like bird songs and ocean waves. The service already has more than 3 million subscribers.

Despite these inroads, Japan's Electronic Industries Association is not overly optimistic. Tamotsu Harada, the organization's manager of the overseas public affairs office, told us in Japan that, while the estimated domestic market continues to grow, "the consumer market is a mature market, so we cannot expect to see any drastic increases."

SOUTH KOREA MOVES AHEAD. The major consumer electronics producers in South Korea are Samsung Electronics Co., Goldstar Co., and Daewoo Electronics Co. All three firms are part of the conglomerates called *chaebols*.

Korea's principal consumer electronic products are black-and-white and color TV receivers, videocassette recorders (VCRs), radios, car stereos, audiocassette tape recorders, amplifiers, tuners, microwave ovens, telephones, refrigerators, and electronic watches.

The country produces about 15 percent of the world market for color TV sets and VCRs and about 25 percent of the world market for microwave ovens.

Most Korean firms are still in the very early stages of manufacturing high-technology and high-value-added products. But in certain areas, like HDTV, where Korea is far behind the Japanese, industry-wide efforts are being made to develop these capabilities faster.

For example, pilot HDTV sets are expected to be developed by 1993. Toward this end, Goldstar in February signed a contract with the United States' Zenith Electronics Corp. for technical cooperation in HDTV and other areas. Goldstar also bought 5 percent of newly issued Zenith common stock.

Additionally, vigorous R&D activities are carried out in core electronic components for which Korean firms still have to depend on Japanese technology (parts for camcorders and large-screen TV receivers, for example). Most Korean firms operate their own research institutes.

The Government's support for consumer electronics is small compared to its aid to other programs like industrial electronics [see "How government helps," p. 53]. One exception is HDTV. The Government will support about 40 percent of the total HDTV development cost, which is estimated to be 100 billion won (US \$140 million) by 1993 when the project is completed.

In the long run, Korean electronics firms are expected to remain as important players in the world markets despite current problems marked by eroding price competi-

tiveness. But technology development will remain a challenge and collaboration with foreign partners will be essential.

One of the areas where Korea shows signs of a competitive race is digital pianos. Goldstar and Korea Electronics Co. are proceeding with plans to mass-produce the instruments. Daewoo Electronics is offering four digital pianos, and Young Chang Akki will produce its own as well as Kurzweil digital pianos.

In microwave ovens, Samsung, Goldstar, and Daewoo controlled the global market from 1985 to 1988, but now the demand has declined. To regain their competitiveness, the companies are developing products with high added value such as over-the-range models (Samsung) that feature 10 variable power levels (for cooking versatility) and combination microwave and grill-convection ovens (Goldstar).

TAIWAN GOES HIGH-TECH. Electronics has been the No. 1 industry in Taiwan since 1984, when it surpassed textiles. But most of the consumer electronics part of that industry was built on low-end products—TV sets, VCRs, telephones, calculators, cameras, and electronic watches. Now, faced with inflation, rising labor and land costs, and an unfavorable foreign exchange rate, consumer electronics manufacturers such as Tatung, National, Sampo, Philips, and others are making R&D commitments as they shift their focus to high-value-added products.

To offset the high labor costs, Taiwan is shifting the production of such products as audio and video equipment to China and Southeast Asia. Since direct investment in China from Taiwan is not permitted, the usual method around this restriction is indirect investment through Hong Kong. In fact, most of the manufacturers in Taiwan are viewing China as their future production base for all products except high-end units.

Examples of this trend include Sonovox, a leading maker of car audio speakers. It plans to start producing high-end models in the near future and move production activities to China. R&D activities will remain at home.

Zylux, also a car audio manufacturer, has begun producing low-end models in China. Only R&D and quality control activities are still based in Taiwan.

Malaysia is another country benefiting from Taiwan's production moves. Action, a Taiwanese audio and video equipment manufacturer, has set up a local subsidiary, Action Industries, in Malaysia. There the company will move into production of color TV sets. Taiwan's Deng Tsair, a high-fidelity audio speaker manufacturer, is also building a plant in Malaysia.

Some companies are using automation to compete. In Taiwan, China Magnetics Corp., said to be the world's third largest supplier of videotape recorders to original-equipment

Television in East Asia

	TV sets per 1000 people	TV channels ^a	TV transmitters	TV stations
Japan	609	6	3745	105
Hong Kong	426	4	4	4
Singapore	315	1	3	3
South Korea	278	4	688	88
Malaysia	144	5	68 ^b	68
Philippines	46	11	30	30
Indonesia	65	20	38	18
Thailand	108	5	86	5
Vietnam	37	1	18	5
China	127	48	65 ^b	29

^a Definitions of channels, transmitters, and stations vary.

^b Excludes low-power relay stations.

Source: 1989 data from Johns Hopkins University, as cited in the *Far Eastern Economic Review*, Nov. 29, 1990

manufacturers (OEMs), invested US \$10 million in production equipment last year and plans to invest another \$10 million this year.

In HDTV, this year Taiwan's Industrial Technology Research Institute (ITRI) will begin a five-to-six-year R&D program to develop a working HDTV receiver prototype. The project is expected to cost US \$192 million, which will come from the Ministry of Economic Affairs. While most of the R&D will take place in the ITRI laboratories, some will also be pursued in several Taiwanese universities. Ultimately Taiwan will probably focus on many niche component markets like video compression ICs and monitors.

UPGRADING IN HONG KONG. Hong Kong's electronics industry started in the 1960s with the assembly of transistor radios. Today, Hong Kong companies such as Porro Technologies, a division of the Paul + Thomson group, manufacture products such as workstations for export to Australia and the Pacific Rim.

But companies like Porro are an exception. Most of the territory's electronics manufacturers have been content to remain as OEMs for market leaders in Japan and the United States. They have left the low end of the market to tiger cubs such as Malaysia and Thailand, where labor costs are far cheaper.

The emphasis remains on manufacturing parts rather than sophisticated systems, partly because of the small size of Hong Kong's electronics factories. Eighty percent of them have fewer than 50 employees.

A report on the colony's electronics industry for January–September 1990, published by the Hong Kong Trade Development Council, lists the city's main export markets for electronic components as China (33 percent), the United States (23 percent), Singapore (11 percent), and Taiwan, West Germany, the United Kingdom, the Netherlands, Japan, South Korea, and Thailand.

In consumer electronics, major exports are radio parts, TV receivers, and sound recorders. Others include liquid-crystal displays, electronic watch movements, and

basic components like connectors, diodes, and capacitors. This month, 25 manufacturers will exhibit at the Summer Consumer Electronics Show in Chicago.

Many component manufacturers have moved their assembly lines to China. Some have also formed joint ventures with their former vendors from Taiwan and Korea and developed their own brand names. But very few of these manufacturers undertake product research and those that do normally cooperate with the multinationals.

SINGAPORE'S MULTINATIONALS. Singapore depends heavily on foreign multinational corporations to set up operations to transfer technology and provide jobs and international links.

The principal consumer products made in the city-state are hi-fi equipment, color TV sets, and audiocassette recorders. But production is a negligible percentage of that worldwide. There are few niche producers. One exception is Robertson Audio, which produces state-of-the-art audio amplifiers selling for US \$5000–\$6000.

Following the worldwide trend toward cooperation to catch up with competitors, France's Thomson Consumer Electronics Co. set up a US \$35.3 million joint venture with Toshiba to design and manufacture VCRs in Singapore. Plant capacity is 4 million units annually.

Another trend is the move toward manufacturing higher-value-added products like high-end hi-fi equipment, stereo color TV receivers, and compact-disc players.

Though a number of companies have set up product development centers in Singapore, they have shifted their manufacturing activities to other countries in the region. This diversion is due not only to the focus on higher-value-added work, but also to relatively higher wages locally than those in other Asian countries.

Chow Tat-Kong, an industry specialist with Singapore's Economic Development Board and its deputy director of systems, does not think that Singapore's higher wages would force all manufacturers to move their factories offshore. "The industry can sustain itself," he told us in Singapore. "The name of the game is very short product life cycles and a short time to market. So long as Singapore is flexible, it still has a lot of room to automate [and increase productivity] to offset higher wages."

Yet another trend is the establishment in the region of VCR and VCR subassembly plants that are supported by parts procurement and production engineering from Singapore. Sony Corp., for example, produces precision head cylinders in Singapore for its VCR plants nearby.

Singapore is encouraging other multinational corporations to manufacture precision components and consumer electronics products there as well. One company that

has responded is Aiwa Co., which spent US \$40 million to expand and automate its audio equipment manufacturing operations and to set up an R&D center there.

INDIA, TOO. One of the objectives of India's Seventh Five-Year Plan for electronics (1985-90) is to produce consumer electronic products economically in volume and sell them at reasonable prices. Toward that goal, estimated 1989 consumer electronics exports of such products as TV sets, tape recorders, and electronic watches, according to the December 1990 issue of *Asia Electronics Union Journal*, were valued at Rs. 300 million (US \$17 million). ◆

COMPUTERS AND ICS: Leading in notebooks, laptops, memory chips

Aldred Rosenblatt Technical Editor,
George Watson Senior Editor

Besides being hot in consumer electronics, East Asian manufacturers have also done well in computers and integrated circuits. The personal computer may have been born in the United States, but most of that industry's fastest-growing offshoots—laptop and notebook computers—are coming from Japan.

Shipments of laptops have outdone those of desktop models, and sales of the smaller notebooks are climbing quickly, too. South Korea, Taiwan, and Hong Kong have also been contesting the PC marketplace, particularly with low-end products. Overall, none has been as successful as Japan, where NEC Corp. is the dominant player. The company accounts for more than half the sales in Japan of PCs, thanks to its 16- and 32-bit desktops and laptop and notebook models. For example, its 98 Note notebook is doing well against Toshiba Corp.'s Dynabook, which was the first of its kind when introduced in 1989.

However, so far, Toshiba has sold the most small computers, including a laptop with a color liquid-crystal display in its product line. Another noteworthy machine is the FMR Card PC from Fujitsu Ltd., the first notebook PC from Japan to rely on semi-

conductor memory cards instead of electromechanical disk drives. Now that worldwide standards are set for such cards, many believe they will be the wave of the future for PCs. (Fujitsu joins others with memory-card PCs. United States-based Hewlett-Packard Co. unveiled its 0.3-kg HP 95LX MS-DOS palmtop model within a day or so of Fujitsu's announcement in April, and another U.S. company, Poqet Computer Corp., began shipping its Poqet PC early last year.)

ON A PAR. But Japan's expertise is not confined to personal computers. During the '80s, the Japanese computer industry emerged as the principal competitor to the United States in a wide range of products, according to a U.S. Department of Commerce report, *The Competitive Status of the U.S. Electronics Sector* (April 1990). At the systems level, the Japanese are "nearly on a par with U.S. firms in hardware design," concluded the report. "Their large-scale mainframes and supercomputers match the best that the United States has to offer in single processor performance."

The Japanese are serious challengers here. NEC, for example, claimed that its SX-3 supercomputer was the fastest in the

world. Hitachi said its M-880 mainframe series was the world's fastest when it was launched in June 1990. The following September, Fujitsu claimed the speed record for its new M-1800 mainframe. Further, Fujitsu and NEC have introduced parallel, multiprocessor systems, as well.

Japanese companies have also been embarking on joint ventures, setting up factories abroad and buying companies in the hope of overcoming threats of protectionism in overseas markets and combatting the appreciation of the yen. Last year, for instance, Fujitsu bought Britain's top computer maker, ICL PLC, for US \$1.29 billion.

The workstation market is another area where the Japanese are setting their sights. Matsushita Electric Industrial Co. last year announced a 32-bit Unix-based workstation. It is also collaborating on a new engineering workstation with Solbourne Computer Inc. in the United States. Other competitors in this arena include Sony Corp., with its NEWS workstation, as well as Mitsubishi Electric Corp. Mitsubishi added to its clout in Europe last year when it purchased the workstation hardware product line from Britain's Apricot Computer Inc.

Japan's manufacturers are also making their mark in computer peripherals, including liquid-crystal displays, laser printers, high-capacity floppy drives (at 2.88 megabytes and up to around 20 Mbytes), and large-capacity storage systems such as optical-disc drives. Canon supplies its laser printer "engine," for example, to a worldwide array of companies and is said to own some 80 percent of this market.

THEIR OWN NICHES. Of Asia's four tigers, each has made a niche in some aspect of computer manufacturing. South Korea and Taiwan have done well producing low-priced IBM PC XT and PC AT compatibles for export, while Hong Kong has developed a significant business manufacturing motherboards and other assemblies. But recently, as PC sales trailed off in the United States and Europe, and as the tigers' own labor costs have increased, the tigers' manufacturers have sought more ambitious products.

At least a dozen companies from Taiwan, for example, announced workstations at last November's

Leading Asia-Pacific semiconductor companies*

Rank	Company and country	1990 revenue, US \$ millions	Percent market share
Japan market			
1	NEC Corp., Japan	3 644	16.0
2	Hitachi Ltd., Japan	2 763	12.2
3	Toshiba Corp., Japan	2 650	11.7
4	Fujitsu Ltd., Japan	2 162	9.5
5	Mitsubishi Corp., Japan	1 642	7.2
6	Matsushita Electric Industrial Co., Japan	1 559	6.9
7	Sharp Corp., Japan	1 100	4.8
8	Sanyo Electric Co., Japan	1 033	4.5
9	Sony Corp., Japan	905	4.0
10	Rohm Co., Japan	632	2.8
Asia-Pacific market outside Japan (mainly Taiwan and South Korea)			
1	Toshiba Corp., Japan	630	8.5
2	Samsung Group, Korea	627	8.4
3	Motorola Inc., United States	528	7.1
4	Hitachi Ltd., Japan	367	4.9
5	Philips NV, the Netherlands	348	4.7
6	Texas Instruments Inc., United States	308	4.1
7	NEC Corp., Japan	304	4.1
8	Intel Corp., United States	299	4.0
9	National Semiconductor Corp., United States	295	4.0
10	Sanyo Electric Co., Japan	278	3.7
North American companies		2 478	33.3
Japanese companies		2 946	39.6
Asia-Pacific companies		1 169	15.7
European companies		847	11.4
		1 410	100.0

*Preliminary estimated market share rankings.
Source: Dataquest, January 1991

Comdex computer show in the United States. The products were built around the 20-MHz Sparc chip set from LSI Logic Corp. But this chip set could itself present a problem because it is applied to low-end workstations, an area where workstation leader Sun Microsystems has slashed prices.

Thus, Taiwan's manufacturers are considering higher-performance, 40-MHz workstations, and the addition of special features. For example, Tatung Co., the island nation's largest PC products maker, offers a workstation with a VMEbus, instead of the Sun S-bus, and an optional DOS coprocessor board. Likewise, Korea's Goldstar, Hyundai Electronics Industries, and TriGem Computer are developing workstations based on Sun's Sparc.

Critical to the switchover is the long-standing ability of these manufacturers to adapt quickly as technologies change. Taiwan, for example, has roughly 200 computer makers turning out laptop and notebook computers, as well as desktop units. Also required is a change in the image these makers have as low-priced producers.

Similarly well-established in the computer world is Singapore, which is noted for its assembly of Winchester disk drives; it claims to produce some 60 percent of the world's dollar volume. But Singapore's Government is encouraging companies to invest in higher-valued-added activities like circuit and system design.

From its modest start in transistor radios, Japan has risen to become preeminent in the world's integrated circuit market and is likely to remain so. About half the ICs produced globally, as measured in U.S. dollars, come from Japanese companies, while U.S. companies account for one-third and all of Europe for one-tenth. The balance is largely made up of other Asian IC producers, notably South Korean.

Among the top 10 IC manufacturers in the world are six Japanese companies: NEC, Toshiba, Hitachi, Fujitsu, Mitsubishi Electric, and Matsushita Electric Industrial. With their strength resting largely on their memory chips, these companies have consistently been the first with the most to market in static and dynamic RAMs (SRAMs and DRAMs)—achievements that have built up a powerful momentum in driving memory technology forward.

Of these six companies, all but NEC Corp. have announced working 64M-bit DRAMs—a capacity 16 times greater than that of the most advanced DRAM chips now in volume production. Though the 64M-bit chips are laboratory made, their public announcement suggests that the companies have a strong advantage in bringing them to large-scale factory production in perhaps two years. Moreover, DRAMs are a bellwether IC; the fine-line geometries and delicate deposition and implantation techniques developed for them eventually find their way

into other kinds of chips.

Japan's success in memory chips is not without its ironies, however. As production has soared, prices have softened. To insulate against such fluctuations, Japanese companies are making stronger efforts in marketing other kinds of chips, application-specific ICs (ASICs) in particular, with world demand for ASICs increasing at 20 percent a year.

But the country's manufacturers have had

Japan," he told *IEEE Spectrum*. "Many U.S. companies cannot make fine lines, so they need Japanese technology for production. But maybe design of new architectures will still be done in the United States. Both sides need each other."

Indeed, the growing alliances between Japanese and North American and European chip producers attest to mutual dependence. "International collaboration is widespread," Kunihiiko Kawada, a senior analyst with the Tokyo branch of James Capel Pacific Ltd., told *Spectrum*. "Toshiba and Motorola have a relationship in R&D and production. Hitachi and Texas Instruments are getting on well together. In Europe, Toshiba has a close relationship with Siemens in memory chips." Other notable East-West memory chip alliances include NEC-AT&T, Oki-SGS-Thomson, and Sony-American Micro Devices.

Another powerful motive for seeking transnational cooperation is Japan's desire to steer clear of trade conflicts. "To avoid friction, Japanese makers will move more into collaboration," Kawada said.

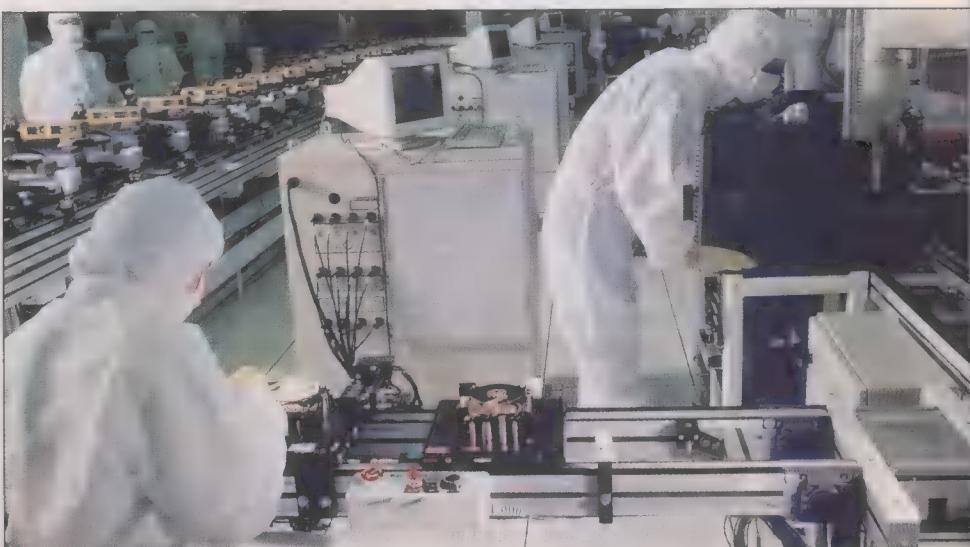
Microprocessor technology remains a sore point, however. Fujitsu Ltd. earlier this year acquired rights to develop reduced-instruction-set computer (RISC) microprocessor chips from MIPS Computer Systems Inc. Fujitsu and Toshiba acquired rights to Sparc RISC chips from Sun Microsystems Inc. But RISC chips are simpler than complex-instruction-set computer (CISC) chips, the traditional type of microprocessor. They do not test a manufacturer's mettle the way CISC chips do, and their sales—for the present, at least—are a small fraction of CISC sales. Meanwhile, Motorola and Intel steadfastly refuse to license their high-end CISC microprocessors to anyone.

Japanese companies may try to leapfrog

South Korea has astounded the world in growing from a minor supplier of discretes to a major presence in ICs

less luck with microprocessor chips. NEC, for example, was thwarted in an attempt to emulate an Intel 32-bit microprocessor when the U.S. manufacturer brought suit. Though Japanese companies have developed their own 32-bit TRON series, its use is limited essentially to their own computers. Here Japanese efforts to market them are hampered by a lack of the widely accepted design tools and application software that underlie the advanced processor chips made by such U.S. giants as Intel, Motorola, and Texas Instruments.

CROSS-BORDER COLLABORATION. Toshiaki Ikoma, a professor at the Institute of Industrial Science of the University of Tokyo, believes that the Japanese and U.S. semiconductor industries are complementary. "Japanese and U.S. companies will collaborate, with design from the United States and manufacturing technology from



About one in every 10 personal computers made each year is produced in Taiwan, among them these AST PCs being produced in Hsinchu. Of Asia's tigers, both Taiwan and South Korea have developed healthy export markets for their IBM PC XT and AT compatibles.

RISC and CISC technology by adopting bold new architectures. Mitsubishi, Sharp, Matsushita, and Sanyo Electric are exploring dataflow architecture, an efficient way of handling instructions that can match the throughput of CISC microprocessors without their extreme complexity. An entirely new software base would have to be developed, however. The Ministry of International Trade and Industry (MITI) has already sponsored much dataflow research, and Hitachi Ltd. is privately funding research at the University of California at Berkeley. Sharp began selling ■ dataflow processor in January, and Mitsubishi expects to introduce a similar chip.

Another likely target for Japanese expansion is embedded controller chips. The world market is expected to grow from US \$3.3 billion in 1989 to \$8.3 billion in 1995. Japanese companies have a firm grip on the market for 4-bit microcontrollers used in appliances, and are now aiming at the high-end market for 8-, 16-, and even 32-bit chips dominated by U.S. suppliers.

KOREAN CLOUD. Meanwhile, South Korea has amazed the industry by growing from a minor supplier of discrete semiconductor devices and IC packages to a major presence in the world IC market. Today, South Korea furnishes about 3 percent of the total world market for ICs and 15 percent of the world market for DRAMs.

Samsung Electronics Co. produces both 1M- and 4M-bit DRAMs, and is independently developing a 16M-bit version, scheduled for production this year. The company has ambitions to produce more challenging chips, and has joined Hewlett-Packard Co. in research on RISC chips. This year, Samsung plans to spend 12 percent of its \$1.4 billion semiconductor sales revenues on research and development.

Other important IC producers include Goldstar Electronic Devices Co. and Hyundai Corp. Both produce 1M-bit DRAMs, and Goldstar will soon make 4M-bit chips in volume (using Hitachi-licensed technology).

The small city-state of Singapore makes only about 0.5 percent of the world's IC chips, in terms of U.S. dollars. Chartered Semiconductors Pte. Ltd. (a joint venture of Singapore Technologies and United States-based Sierra Semiconductor Corp.), Hewlett-Packard, Texas Instruments, and SGS-Thomson operate chip factories, producing mostly ASICs. Planning to join forces to build ■ factory for DRAMs this year are Hewlett-Packard, Texas Instruments, Canon, and the Singapore Economic Development Board. Although ICs are largely designed and developed overseas, in the last few years AT&T Microelectronics, Chartered Semiconductors, and SGS-Thomson have become involved in local design and development of circuits.

Singapore's share of wafer fabrication may be small, but its share of IC test and assembly business is significant—about 5

percent of the world's units. Neighboring Malaysia is a big chip packager, too; U.S. companies alone have invested U.S. \$2.2 billion in test-and-assembly factories there.

TAIWANESE TACTICS. Taiwan, stung by a worldwide chip shortage in 1988 that hampered its electronic equipment assemblers, is moving to expand and upgrade its indigenous IC industry. The island's Industrial Technology Research Institute (ITRI) sponsors R&D on sub-micrometer fabrication technology with the goal of achieving 0.5- μm linewidths by 1995. If expansion proceeds as planned, by next year Taiwan will have increased its IC capacity by about 2.5 times the 1989 level. As for now, however, Taiwan manufacturers rely on imports for 80 percent of their chip needs.

Nevertheless, a small but lively IC industry exists—one that ships more than 40 percent of its output overseas and accounts for about 1 percent of world production. The Acer Group is collaborating with Texas Instruments Inc. in a factory near Taipei that will start producing 4M-bit DRAMs later this year. United Microelectronics Corp. makes 1M-bit static RAMs, largely for domestic use. Taiwan Semiconductor Manufacturing Corp. is a joint venture of Philips NV, Taiwan's Government, and private investors.

Hong Kong is the smallest of Asia's tigers in IC production. Other than Motorola's Asia/Pacific Semiconductor Products Division, which is building Silicon Harbour Center for chip manufacture, the industry is run on a small scale. Harry Chan, chairman of Juko Laboratories Ltd., a chip company large enough to do at least some of its own design and engineering, told *Spectrum*, "It's hard to develop big companies here because they lack the funds. The Hong Kong Government should learn from Taiwan and Korea." The Government must be listening to people like Chan because this year it instituted a program to train local designers of ASICs. ♦

AUTOMOTIVE: outside suppliers or in-house development

Ronald K. Jurgen Senior Editor

Among Japan and the four tigers, only Hong Kong and Taiwan steer almost entirely clear of automotive electronic controls. Most electronics in Japanese vehicles are produced by automakers' subsidiaries, affiliates, or associated companies; exceptions are semiconductors, microprocessors, and control units, which are usually made by electronics giants like Toshiba Corp., Hitachi Ltd., and Mitsubishi Electric Corp.

Most of South Korea's car manufacturers also have their own electronics subsidiaries and Singapore does a thriving automotive component business (US \$1.1 billion in 1990).

Of Japan's seven largest car companies—Toyota, Nissan, Mitsubishi, Honda, Mazda, Isuzu, and Suzuki—only Toyota Motor Corp. is already making electronic components for cars in-house. But others are moving in that direction.

Nissan Motor Co. plans trial production of electronic control units in the second half of this year at its Central Engineering Laboratories. In January, Honda Motor Co. opened its Wako Research Center for Basic Technologies, which is conducting basic research in electric cars and navigation systems, among other areas.

Mazda Motor Corp. is producing electronic components through Naldec Corp., a joint venture with NEC Corp. Naldec turns out mostly electronic chassis and engine controls, plus fuel injection systems and the computer control for the carmaker's four-wheel-steering system. Sales in the year ending this past March were US \$69 million.

All Mazda's prototype subsystems are developed at its R&D headquarters. Although parts for those subsystems are bought from others, the systems are built in-house for the sake of security. Only after the prototype is in hand does the company go to outside suppliers with specifications.

As for Toyota, its Hirose plant began producing electronic controls, actuators, and sensors in April 1989. The plant also serves as an automotive electronics research center. By putting both development and production capabilities under the same roof, Toyota hopes to speed up the development cycles for such embryonic items as video displays, audio systems, and car telephones.

One Toyota research official told *IEEE Spectrum* in Japan, "It's no longer enough to ask our suppliers to make custom components. We have to give them some direction. And by having this facility, we can raise our technical capability which, in turn, should have ■ positive impact on our suppliers."

Outside the carmakers but usually affiliated with them are between 50 and 100 first-tier producers of automotive electronic products in Japan. One analyst goes further and claims that, if all subcontractors are included, the number runs into the hundreds.

Nippondenso Co., the largest of the group, has seven plants (although not all are in automotive electronics) and last year reported consolidated sales of US \$11.2 billion. The company's output ranges from door lock controls, sensors, and fuel injection systems to skid controls, cruise and transmission controls, and digital clocks. An affiliate of Toyota, Nippondenso employs about 6000 at its Japanese technical centers and spends nearly 6 percent of its net sales on research (about US \$600 million in 1990).

Other suppliers affiliated with Toyota include Aisin Seiki, Fujitsu Ten, Jeko, Koito, and Tokai Rika. Atsugi Unisia, Calsonic, Clarion, and Hanshin Electric are among nine or more Nissan affiliates. Honda is supplied by Denshi Giken, Honda Lock, Seiki

Giken Kogyo, Stanley Electric, and Toyo Denso. U-Shin Ltd. and YNS have close dealings with Mazda, while Mitsubishi Electric, though not an affiliate of Mitsubishi Motors, belongs to the same Mitsubishi group.

Plainly, Japan plays a full hand of automotive electronic products, from sensors to engine and transmission controls, antilock braking systems, navigation systems, and four-wheel steering.

At present over half of the new vehicles produced in Japan (13.6 million from April 1990–March 1991) are equipped with electronic fuel-injection systems (Nippondenso makes about half of those systems). Toyota hopes to install fuel injection in 80 percent of its cars from 1993 on.

In four-wheel steering, Japan is far ahead worldwide. Nissan adopted electronically controlled four-wheel steering on the 1985 Skyline and has since applied it to several other models. It was the first Japanese carmaker to go commercial with an electronic system (Honda's is mechanical).

Other carmakers with electronic four-wheel steering include Toyota (five models), Mitsubishi (five models), and Mazda (one model). The Mitsubishi Gallant integrates the feature with four-wheel drive, four-wheel integrated suspension, and four-wheel antilock braking.

NAVIGATION SYSTEMS. As of February, five Japanese automobile manufacturers—Toyota (Crown), Nissan (Cedric, Gloria, and Cima), Mazda (Cosmo), Mitsubishi (Diamante and Sigma), and Honda (Legend)—had introduced electronically controlled navigation systems. Toyota did so first, in the fall of 1987, and through 1990 had sold about 131 000 cars equipped with the system, which also doubles as a compact-disc player. Toyota's version, like those of the other Japanese carmakers, operates on the dead-reckoning principle. But the company plans to introduce one based on a geostationary satellite later this year.

In 1988, Toyota introduced traction control on eight models. In 1989, it added active suspension to the Celica Active Sport. The company introduced active suspension last month on a new sporty version of the Lexus. The current Lexus features an air suspension system.

Nissan is offering an optional, fully active suspension on the 1991 Infiniti Q45 for US \$4000. It relies on three vertical gravity sensors to detect changes in vehicle bounce acceleration, and other types to detect pitch and lateral accelerations and changes in vehicle height.

By 1995 or 1996, Toyota told us, it might be able to equip some of its models with 32-bit microprocessors, which would serve to integrate controls for engine, chassis, and brakes.

Fuzzy logic is also on the agenda for Japanese cars. Toyota officials estimate that such systems as speed and brake controls using fuzzy logic could be ready for com-

mercialization in five years. Nissan may be even further advanced. It claims to have patented the basic technology for fuzzy antilock braking systems and transmission controls, and chances are the results will be commercialized within two years.

KOREA GOES IN-HOUSE. Of South Korea's five carmakers—Hyundai, Daewoo, Kia, Asia,

and Mitsubishi and Daewoo with General Motors Corp., for example.

Hard times are the long-term outlook for independent car audio equipment manufacturers as local carmakers reduce their dependence on those firms while increasing in-house supply. Only those manufacturers that invest heavily in technology development for high-value-added products will remain competitive. Those that rely on low-end products will lose ground to competitors in Southeast Asia.

For high-technology engine control units and other automotive electronic products, long-term prospects will depend on the performance of the local auto industry as well as the Government's willingness to support R&D activities for automotive electronics. Efficient technology collaboration with foreign partners will be another important factor.

SINGAPORE BOOMLET. Singapore's automotive components industry hit the US \$1.1 billion mark in 1990. The country has come a long way since the 1960s when production by a handful of companies centered on simple original-equipment manufacturer and replacement components mainly for the domestic market. Now Singapore is viewed as a major manufacturing base, particularly for the production of higher-value-added engineering systems.

The engineering development content of major manufacturers has been growing with greater autonomy of product design, purchasing, and materials control functions. But the country's continuing focus is on niche products or activities such as vehicle controls and car navigation systems and on firms that can utilize advances in technology to design and produce new generations of components.

Today a broad range of components are being produced, including subsystems like ignition control modules and pressure sensors. GM Singapore, a wholly owned subsidiary of GM's Delco Electronics Division, for example, has a workforce of 2500 employees. They manufacture engine control

By the mid-'90s, Toyota might be using 32-bit chips to link engine, chassis, and brake controls

and Ssangyong—all but Asia Motors Co. operate their own electronic subsidiaries. They are Hyundai Electronics, Daewoo Electronics, Seungri Electronics for Ssangyong Motors Co., and Tripoli Electronics for Kia Motors Co. For more sophisticated electronic products such as engine control units, two major firms are also owned by carmakers: Kepico by Hyundai Motor Co. and Daewoo Precision by Daewoo Motor Co.

There are also about 100 car audio and compact-disc player makers in Korea, including Yung Tai Electronics, Woo Jin, and Tongkook who depend mostly on foreign markets. In car audio, local firms have attained a fairly high degree of technical know-how; Yung Tai Electronics, for example, will introduce compact-disc changers for cars next month.

In most other areas, however, no impressive progress has been made. Such products as antilock braking systems are imported. Last year, in fact, South Korea designated automotive electronics as a strategic industry to be aided by the Government, but no detailed R&D support plan has been revealed.

Within Korea's boundaries, companies do not collaborate, but internationally they are active—Hyundai with Robert Bosch GmbH

A sampling of Japan's auto electronics suppliers

Company	Location	Estimated 1990 billions	Affiliations; products
Nippondenso Co.	Kariya, Aichi prefecture	1151 ^a	Affiliate of Toyota Motor Corp.; diversified products
Aisin Seiki Co.	Kariya, Aichi prefecture	729 ^b	Affiliate of Toyota; transmissions, brakes
Mitsubishi Electric Corp.	Tokyo	310 ^b	Member of Mitsubishi Industrial Group; diversified products
Calsonic Corp.	Tokyo	255 ^b	Subsidiary of Nissan Motor Co.; air conditioners, heaters, and so on
Sumitomo Electric Industries Inc.	Osaka	230 ^c	Leading electric cable maker; wire harnesses
Hitachi Ltd.	Tokyo	200 ^a	Close ties to Nissan; diversified products

^a Estimate by parent company of its auto electronics sales only.

^b Estimate by S.G. Warburg Securities (Japan) Ltd.

^c Estimate by investment analyst.

modules, audio systems, pressure sensors, voltage regulators, and other products for worldwide markets that include its parent GM company in the United States, other GM affiliates like Daewoo, Suzuki, and Holden, and non-GM firms like Fiat.

AUTOMATION: extending electronics in manufacturing

John A. Adam Senior Associate Editor

In applying automation to production, be it of microchips, cars, or even skyscrapers, Japan is often the world leader. Its frequent labor shortages coupled with rising global competition—including new entrants from East Asia—are pressuring the country to automate more intensively and extensively, by means, for instance, of computer-integrated manufacturing and fuzzy logic. Among the Pacific Rim's four tigers, Korea by the next century will be exporting a few robots, and Singapore's Government is pushing R&D in the area.

Of the industrial robots in 16 leading industrialized countries in 1989, about two-thirds were employed by Japan. "If you calculate that one robot can do four times the work of a person, then the number is actually equivalent to about 2 million workers," Fumio Harashima, a professor at Tokyo University's Institute of Industrial Science, told *IEEE Spectrum*. Factoring in other factory automation tools, such as computer numerically controlled (CNC) machines and transportation, as well as storing machines such as unmanned forklifts, then Japan's tireless unmanned workforce becomes even more significant.

According to the Japan Industrial Robot Association (JIRA), the number of robots installed in Japan has more than doubled since 1986 and will double again by 1995. While many U.S. companies have abandoned or sold their robot business, JIRA counts some 230 robot companies in Japan. Fanuc Ltd., Kawasaki Heavy Industries Ltd., and Yaskawa Electric Manufacturing Co. dominate. Fanuc is building a new factory that should treble its robot output to 9000 units annually; a new unmanned factory by Yaskawa will enable it to double output also, to 9000 units a year. The Kawasaki company expects to expand production from 2100 units a year. Japan exports about 20 percent of its

Kia Motors' assembly line for Pride autos in Sohari, South Korea, employs many robots. The plant can produce 350 000 vehicles a year, many of them for export to the United States, Europe, and the Philippines.

robots, mainly to the United States, but the introduction of more Japanese automobile plants in Europe is expected to boost sales there.

ROBOT PROGRESS. Fanuc has developed an integrated system that controls a robot through a CNC device installed in the machine tool. It is expected to save on costs and ease coordination. Toshiba's two-armed ARI robot demonstrates advanced machine vision and assembly techniques as it builds lego bricks like a small child.

As for fuzzy logic, its industrial application has been spreading in Japan since 1983 and by now extends over everything from making sake to fabricating steel. According to one report, fuzzy control of blast furnaces is saving the big Nippon Koshuha Steel Co. about US \$700 000 annually. Recently, Japan's Ministry of International Trade and Industry (MITI) and the Science and Technology Agency (STA) created the Laboratory for International Fuzzy Engineering Research into such subjects as the fuzzy control of robots and atomic power stations. The lab will complement an STA five-year fuzzy logic program begun in 1989.

The ferocity of the fight in Japan to accelerate production processes while minimizing mistakes is winning converts to computer-integrated manufacturing (CIM), where manufacturing processes from design to marketing are coordinated by a computer and communications network. For example,

Hitachi Ltd.'s Tokai Works was taking 10 weeks from receipt of an order for a videocassette recorder to its fulfillment, and in the hope of cutting that to six weeks added an optical local-area network to tie in mostly existing equipment. But perhaps the main users of CIM are the steel and automobile companies, and the main suppliers, electronics companies such as Toshiba Corp. and NEC Corp.

In the chip industry, automation has dramatically speeded up surface-mounting without downgrading the placement of components. The parts commonly take only 200 milliseconds each to mount, with accuracy as high as ± 100 mm. Japanese firms dominate, but are being pressured by a few companies in Korea and Taiwan, which are producing models as fast and accurate as those in Japan and plan to make machines with vision systems soon.

Many Japanese firms plan to expand factory automation significantly. At any rate, both Kyushu Matsushita Electric Co. and TDK Corp. intend to pursue 20 percent sales growth in factory automation equipment.

KOREAN CNC. In Korea, the domestic production of computer numerically controlled machines took off only in the early 1980s. Since 1987, domestic producers have enjoyed rapid growth as sales passed the 2000-unit mark. About 20 Korean firms produce the machines, including Daewoo Heavy Industries, Tongil, Whacheon Machinery Works, Kia Machine Tool, Korea Machinery, Doosan Manufacturing, Hyundai Motor, and Samsung Shipbuilding & Heavy Industries.

Imports of robots have grown about 50 percent a year since 1986. By late 1989, 1200 industrial robots were employed at Korean factory sites, mainly for arc welding, but also for spot welding and assembly. Most are used by the auto industry, followed by the electronics industry. The Ministry of Trade and Industry has published ambitious plans for automation in industry that would, for instance, reduce the manufacturing work week from 55 hours in 1987 to 48 hours in 1993, largely by using mixes of low-cost automation and robotics.

Plans call for Korea to begin exporting a trickle of robots to reach \$3 billion worth by 2000. But Korean robots, though adequate for simple tasks, are reported as not yet competitive with the best in market.

TWO SINGAPORE INSTITUTES. In Singapore, the Government will soon create an institute of microelectronics, to be followed by an institute of manufacturing technology. Computer-integrated manufacturing and inspection are new to Singapore, but LeBlond Makino, South East Asia's leading CNC tool manufacturer, uses its R&D capability in Singapore to make new-generation CNC machin-



ing centers with automatic tool change capabilities. Singapore's Government is encouraging its industry to automate further; printed-circuit board assembly is among the beneficiaries. ♦

TELECOMMUNICATIONS: attracting players to a global market

Trudy E. Bell Senior Editor

In the last five years, the Asia-Pacific countries have become one of the biggest markets in the world for telecommunications. Many rural areas are still without plain old telephone service (POTS), providing ample opportunities for companies in Europe, Japan, and the United States to supply handsets, subscriber lines, cables, exchanges, switches, and satellite earth stations.

The scale of the market for POTS alone is significant: although China and 14 other Asia-Pacific nations have half the world's population, they have only 17 percent of its 500 million telephones.

But the sophisticated services are also in demand. The number of cellular phones is nearly doubling each year, particularly in Japan, South Korea, and Singapore. The Pacific Rim region has installed or put into use four submarine optical-fiber cables for long-haul data and voice communications between itself and the rest of the world, and has plans for another 11.

Domestic communications satellites are particularly important for Indonesia, the Philippines, and Hong Kong, and Korea has announced its intent to get into the business as well. Hong Kong is aiming for a world's first: in 1994, it plans to complete the final phase of its switch to an all-digital telephone network, to be followed by Singapore's in 1995 and Japan's in 1996.

To further encourage all this technological development, many of the countries are disbanding their government monopolies on telecommunications in favor of deregulation and the admission of private enterprise—a movement toward privatization (sometimes called liberalization) that follows the pattern set in the last half decade in Great Britain, Japan, and the United States.

EXPLODING MARKET. According to a study by the consultants Arthur D. Little Inc., Cambridge, Mass., the Asia-Pacific telephone networks are expanding by 6.7 percent a year, ahead of Europe's 4.4 percent and North America's 2.8 percent. In parts of Asia, international calls are growing by up to 40 percent per year. In Hong Kong, so many businesses are connecting facsimile machines and computers to their telephone lines that data traffic is increasing 80 percent per year.

This dramatic need for telecommunications equipment of all kinds has attracted

suppliers from all over the world, ranging from Northern Telecom of Canada, Alcatel of France, Siemens of Germany, L.M. Ericsson of Sweden, and AT&T, IBM, and Motorola of the United States. The Asia-Pacific Rim's only contenders at home are Japan's Fujitsu Ltd. and Nippon Electric Corp. (NEC), but they are also getting into the act with joint ventures.

"In Japan, 3 million fax machines generate more international calls than 48 million telephone sets," said Simon Krieger, head of AT&T Hong Kong Ltd. "Over half of the communication between Hong Kong and the United States is in fax messages."

Japan's Nippon Telegraph & Telephone Corp. (NTT) has begun converting its telephone lines to integrated-services digital network (ISDN). The country anticipates that its network will be 80 percent digital by 1995—and 10 percent broadband by the end of the decade. Such a system would be capable of delivering digital high-definition television (HDTV) signals.

Although reliable figures on the size of the Asian market are difficult to come by, various published estimates suggest that this

More than half of the communication between Hong Kong and the United States is by facsimile

year alone the Asia-Pacific market will be around US \$70 billion–\$75 billion, and may grow by 10 percent per year throughout the decade. For comparison, public telecommunications operators in the Organization for Economic Cooperation and Development (OECD) invested an average of more than US \$64 billion between 1986 and 1988. (Both sets of figures are heavily skewed by Japan, Asia's only OECD member, which accounted for about US \$50 billion in 1990.) By 1992 the region's share of the world telecommunications market is projected by Arthur D. Little to be nearing one-third.

LESS IS MORE. Japan's NTT changed from a government-run monopoly into a private company in 1985 [see "Japan telecommunications at the crossroads," by Tadao Saito, *IEEE Spectrum*, November 1990, pp. 126–128]. The aim was to encourage competition from private companies and drive down prices. Now the country has hundreds of competing carriers and value-added network suppliers, and the cost of domestic and international calls has plunged.

Other Pacific Rim countries are following suit. In South Korea, the Government's Korea Telecommunications Authority is facing competition this year in international voice services from Dacom, a company

originally set up in 1982 to provide data services.

Taiwan, as the first step in phased privatization, plans to turn its state-run telecommunications monopoly, the Directorate General of Telecommunications, into a private corporation within the next two years.

Plans are also in hand to privatize Singapore Telecom, which runs all telephone and postal services in the republic, by the end of 1992. Malaysia and Thailand, too, have taken steps toward privatizing their telecommunications authorities.

WALKIE-TALKIES. Cellular phones have been available in Japan since 1979, when NTT began offering cellular service to Tokyo. Since 1980 the number of units has grown by a steady 50 percent per year. But only since NTT took its service nationwide in 1984 did the business begin to reach big numbers, from about 150 000 mobile phones in use in 1987 to 550 000 last year; estimates for this year top 1 million. Japan's Ministry of Posts and Telecommunications has increased its projections that national demand will surpass 8 million portable phones by the year 2000.

Japan is not alone in this boom. In Hong Kong, with a population of 6 million, cellular units are selling at a rate of 40 000 per year. This March, its Government licensed four separate consortia to operate the territory's new CT-2 telepoint mobile phone service. Service is expected to start by year-end, and to extend to most of the territory's urban areas.

Hong Kong also has 700 000 subscribers to radio paging services; that works out to a penetration rate of 12 percent of the population, the highest in the world. And more than 110 000 users of cellular mobile phones give the territory a penetration of 2 percent, second only to the proportion in northern Scandinavia.

In Taiwan, the telecommunications directorate has allocated more than 100 000 channels and has said that within four years 300 000 frequencies would be available. After the initial rush to buy cellular phones, sales have leveled off to about 2000 units a month.

According to the principal vendors, the demand is damped by Taiwan's lack of a telecommunications infrastructure, delayed introduction of hand-held models (only mobile car phones are available), high import duties, and rates more than 10 times those for normal local calls.

Meanwhile, Thailand's infrastructure is stretched beyond capacity. The waiting list just for basic telephone service consists of 600 000 people. For cellular service, only 300 of the 15 000 subscribers to the Telephone Organization of Thailand system can use their phones at the same time. The same is true for the country's only other network, the Communication Authority of Thailand.

TOUCH OF GLASS. With international telecommunications traffic growing at up to 25

percent a year in parts of the Asia-Pacific region, submarine cable capacity is being added quickly to cope with the flow of data among banks, stockbrokers, and airlines, as well as with a dramatic increase in voice traffic.

Fifteen cable systems are either now operating or are planned for the region. When all have been completed in 1995, the region's private companies and telecommunications authorities will have spent about US \$3.5 billion on submarine fiber cables since 1989. These cables will link Australia, Brunei, Canada, Guam, Hong Kong, Japan, the Republic of Korea, New Zealand, the Philippines, Taiwan, Thailand, Singapore, and the United States.

Hong Kong Telecom has laid about 28 000 km of optical fiber within its borders, and has digitized more than 60 percent of the exchange lines. According to Chinese University vice chancellor Charles Kao, a pioneer in the development of optical fibers in the 1960s, Hong Kong should accelerate development of its high-tech industries by developing a territory-wide digital optical-fiber highway. Although such a network would cost about US \$800 million, Kao believes the per capita cost would be much lower than that for a similar network anywhere else in the world because of the territory's small area and dense population.

SATELLITES VS. TRADITION. Indonesia, a country of some 13 500 islands and a population of more than 180 million, has one of the lowest densities of telephones in Asia, with only 0.5 phone per 100 people as of year-end 1989. A quarter of them are in the capital city of Jakarta alone.

Many islands have no phone service at all. Much of the internal communications across the far-flung country are carried out via Indonesia's home-built Palapa communications satellite system. That system is also used by Malaysia, Papua New Guinea, the Philippines, Singapore, and Thailand, primarily for television broadcasting. In essence, Palapa has become a regional system.

More recently, a regional communications satellite, AsiaSat-1, launched last April from the Xichang site in the Chinese province of Sichuan, has a northern footprint that covers the People's Republic of China, Hong Kong, Japan, South Korea, and Taiwan [see illustration]. Already having created a major stir in the global commercial launch market ("Aerospace and military," this page), AsiaSat-1 now promises to change the television viewing habits of millions of Asians.

A big piece of Asia Satellite Telecommunications (the international consortium responsible for the launch) is owned by Hutchinson Whampoa, a Hong Kong company. One of its subsidiaries, Hutchvision, recently announced that it would rent a dozen of AsiaSat's transponders to beam television programming to rooftop receivers throughout much of Asia. The prospect has disturbed several governments that try to control their citizens' access to the media; Singapore, for example, officially bans its population from owning satellite receivers.

But the news had its greatest impact in Hong Kong. In late 1989 the territory's Government awarded a franchise to the consortium Hong Kong Cable Communications (HKCC) to wire up the territory for cable

television. The consortium hoped to serve more than 1 million homes by 1995, an ambitious goal since the world's largest cable network presently covers little more than 300 000 homes.

But after Hutchvision's satellite TV proposal, HKCC pulled out of its cable commitment. Now Wharf Holdings, which was one of HKCC's members, has announced that it hopes to offer cable TV in Hong Kong beamed by microwave. Local television station TVB has announced plans for a similar cut-price scheme.

Sir Peter Blaker, chairman of the Anglo-Hong Kong Parliamentary Group, speaking at a conference on cable and satellite television in London in March, summarized the impact of a communications satellite in Asia as encouraging changes "on a scale and at a pace that promises to outstrip its North American and European counterparts. The social, political, and economic implications are profound."

AEROSPACE & MILITARY: setting targets throughout the region

Karl Esch Contributing Editor

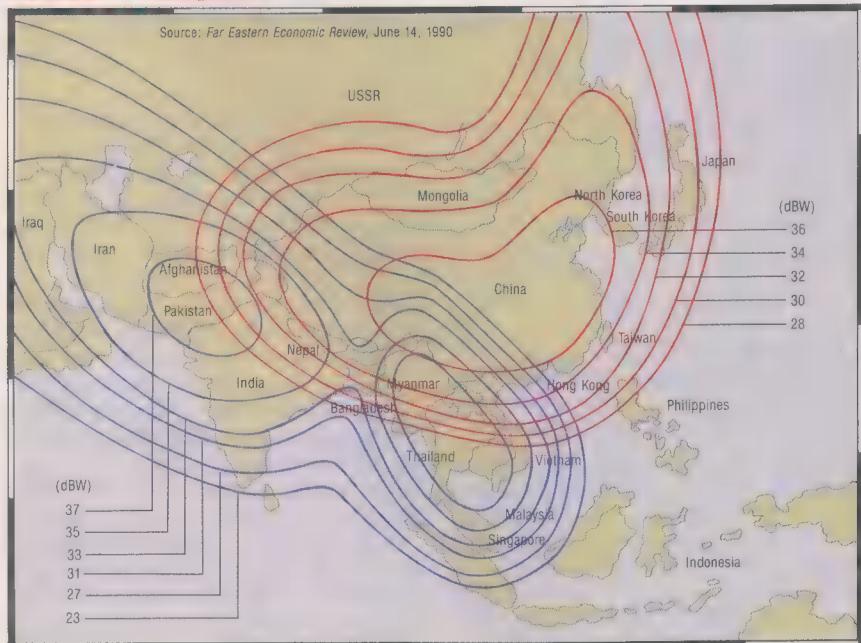
Aerospace has become a guiding star for many Asian countries. They see aircraft development and space exploration as steering their technology into the 21st century. In the lead, last year Japan sent its first spacecraft around the moon—the first lunar probe by any country in 14 years, and the first that was neither American nor Russian. Meanwhile, the People's Republic of China sent aloft its first commercial payload for a foreign company: the home-built Long March 3 rocket carried a communications satellite for a Hong Kong-based consortium, sending the first direct-broadcast television images to all of Asia.

But even such feats pale before the nations' long-range commitment. Japan, where the top aerospace companies are solidly rooted in electronics and heavy industry as well, is targeting fighter planes, commercial air transport, and space technology to make itself a first-rate aerospace power.

Singapore, Indonesia, and Malaysia, for lack of a comparable industrial infrastructure and comparable economies of scale, are bootstrapping their way in commercial air transport through contracts that let them learn by doing: first becoming centers of repair and maintenance, then manufacturing smaller components, then assembling aircraft from kits. Their ultimate aim is to design and build complete aircraft within their borders. South Korea and Taiwan each have passed a slab of legislation restructuring their entire industry to spur the development of aerospace companies.

And all are developing cooperative alliances both within their own domestic indus-

AsiaSat 1 footprints



Northern (red) and southern (blue) footprints of the AsiaSat-1 communications satellite cover all of eastern and western Asia with television programming and telephone communications. AsiaSat-1 was launched last April from China; it is owned and operated by a Hong Kong-based consortium. Signal power received on the ground is shown in decibels above 1 watt.

try and with one another and with established aerospace companies in the West. With the first, they gain economies of scale; from the second, they learn technologies and management techniques. "The strong growth in Asian aerospace is driven by the economies of the countries involved, which are adapting their industries to aerospace manufacturing," said Thomas Hung, managing director of Aviall Airstocks and president of the Hong Kong International Aerospace Forum. "Japan is probably in the lead, but is closely followed by Korea and China, which are using Government support to push themselves into the aerospace sector."

JAPANESE FIGHTERS. On the military side, Japan has had a domestic aircraft industry since the 1920s, one that rose to world class in World War II. Since then it has worked closely with U.S. aircraft manufacturers. Setting a trend that their Asian neighbors are now following, the post-war Japanese aerospace industry re-started with maintenance contracts on primarily military aircraft and then commercial transports far away from regular repair depots.

Today 80 percent of Japanese aerospace spending is from defense-related contracts for the country's self-defense forces (Japan's constitution prohibits conventional all-purpose forces).

By 1987 the country had built several aircraft from original designs—including supersonic trainers—and others of foreign design under license. It then announced its intention to produce a state-of-the-art all-Japanese air-superiority fighter to be called the FSX, for its Air Self-Defense Forces. About a year later, the Japanese Government decided to base the FSX fighter on the F-16 Falcon and the derivative F-16XL of the United States' General Dynamics Corp.

The more-or-less proven design frees FSX prime contractor Mitsubishi Heavy Industries Ltd. to explore a wider range of new technologies without the risks inherent in starting from an original concept. Of particular interest to the Japanese is the F-16's use of composite materials, for both its lightweight structure and its "stealthy" invisibility to radar.

One serious difficulty facing the Japanese FSX team is development of the source code software for the interactive flight control system. This information, which was not part of the General Dynamics' technology transfer agreement, is critical since all the aerodynamic controls on the F-16 are electrically powered and electronically controlled, without redundant mechanical backups. Some observers expect the lack of original source code to complicate the FSX development program.

KOREAN AEROSPACE. South Korea has a smaller industrial base. But it is also keen on corporate alliances. This past March, after two years of negotiation, the Koreans signed a learn-by-doing contract with General Dynamics for 120 F-16s at US \$5.2 billion.

Korea's stated intent in cooperating with

General Dynamics is to glean from this cooperative project the knowledge it needs to develop its infant aerospace industry. By the first decade of the next century, the nation wants to be able to supply its air forces with AFX fighters designed and produced domestically.

The first 12 F-16s will arrive complete and ready to fly from Fort Worth, Texas. The next 36 will be assembled from kits by Samsung Aerospace Industries Corp., Seoul. The remaining 72 aircraft will be manufactured under license by Samsung, with Korean-made parts and subassemblies.

The Koreans will pay for the privilege of learning, since the domestically produced F-16s will be 20–30 percent more expensive than those purchased ready to fly. They are gambling that the lessons they learn will be transferable to the domestic production of the proposed AFX fighter.

In a similar learn-by-doing program, Korea

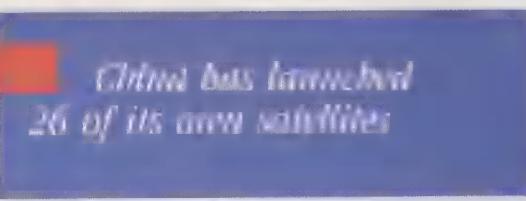
a belief common to all the Asian countries with aerospace ambitions, hopes that the stringent quality controls inherent in aerospace design, manufacturing, and certification will have a positive effect throughout the rest of Taiwan's industrial infrastructure. Taiwan's IDB predicts that its aerospace business could be worth as much as US \$600 million by the year 2000.

COMMERCIAL AIRCRAFT. On the civilian side, declining defense sales worldwide are switching the emphasis to commercial aircraft production, especially by the international big three: Boeing Co., Airbus Industrie, and McDonnell Douglas Corp. The need now is for ever better products at reduced cost, since manufacturing expenses will no longer be subsidized by large military aircraft orders or member governments. Investment risk, in response to tougher loan requirements, must be shared. And aircraft deliveries must be hastened.

At the same time, the commercial airlines and aircraft leasing agents are asking for more adaptable aircraft, whose seating can be easily reorganized and color schemes changed. This adaptability enables them to tailor aircraft for specific service needs, such as offering all-freight flights or single-class-of-service charters, in order to induce customers to stay with specific airlines.

Joint development of new commercial aircraft seems the trend between East Asian nations and the United States. Boeing, for one, has signed memoranda of understanding with Mitsubishi, Kawasaki, Fuji, Shin Meiwa Industry, and Nihon Hikoki, giving the five Japanese companies responsibility for large portions of Boeing's next-generation 777 twinjet transport scheduled for delivery in 1997. The five program partners will build fuselage sections forward and aft of the wing, the wing center section, and the section that contains the aft pressure bulkhead and tailcone. All this amounts to 20 percent of the airframe cost.

Boeing's Japanese partners will necessarily be involved for the life of the 777 program and also share in market risks entailed. Their 20 percent share in the work is an incremental increase in the 15 percent stake the same companies have in current 767 aircraft pro-



is starting to develop its own space technology. Last July, communications minister Lee Woo-jae announced that Korea's first communications satellite, to cost about 300 billion won (US \$40 million), will begin service in October 1995 from a geostationary orbit 36 000 km above the equator.

The satellite, named Mugungwha after the country's national flower, will be designed by Telesat of Canada and Satil Conseil of France. Korea's Electronics and Telecommunications Institute and several Korean companies will develop tracking facilities for the ground segment. The country's domestic participation in the program is therefore limited, but the technological knowhow gained will lay a foundation for future satellite production. Already Korea is planning a completely home-grown satellite for its second, to be launched in 2002.

TAIWAN FIGHTER. Taiwan's industrial base is about the same size as Korea's. It already has a prototype of its Indigenous Defense Fighter (IDF) flying and is planning to build 250. The IDF, also known as Ching-kuo fighter, is configured as a fast-climbing, lightweight defense interceptor for the Taiwanese air force. It can also carry antiship missiles.

Most of its major components come from Taiwan's military Aero Industry Development Centre, not civilian facilities, while critical components, such as its U.S.-built Garrett 1042 jet engines, are from overseas suppliers.

Nonetheless, Taiwan's Industrial Development Board (IDB), voicing

Weapons in Asia

	Human	Missile	Aircraft
China	DEPLOYED	DEPLOYED	DEPLOYED
India	PROD	PROD	DEPLOYED
North Korea	PROD	DEPLOYED	DEPLOYED
South Korea	R&D?	—	DEPLOYED
Taiwan	R&D	PROD	DEPLOYED
Thailand	—	—	DEPLOYED
Vietnam	—	—	DEPLOYED

R&D = substantial R&D estimates.

PROD = production capability or ability to produce within one year.

DEPLOYED = deployed in combat forces or held in combat-ready storage.

? = probable but not confirmed.

Estimates based on unclassified non-U.S. government sources.

Source: Senator John McCain in *Washington Quarterly*, Spring 1991

duction. The first 777 is scheduled for delivery in 1997.

This partnership program is a first for Boeing commercial aircraft operations. While sharing in design, engineering, and manufacturing, the Japanese are still not in on the marketing, sales, and system integration. In the words of David H. Vadas, an economist at the Aerospace Industries Association in Washington, D.C., "It is not in Boeing's interest to give away the store to Japan."

BOOTSTRAPPING. McDonnell Douglas also has arranged with Mitsubishi and Korean Air to make components for the MD-11, the aircraft that succeeds Douglas's pre-merger wide-bodied DC-10. And since 1985 the company has had a co-production agreement with China's Shanghai Aviation Industries Co. to assemble MD-80s, a family of commercial transports descended from the pre-merger Douglas DC-9.

The agreement calls for the Chinese to assemble the aircraft from major subassembly kits, test-fly them, and deliver them to Chinese airlines. The first completed aircraft was delivered in mid-1987. The initial order for 25 aircraft has since risen to 35, with an option for an additional 10. Only a few Chinese parts, the largest being landing-gear doors, make it from Chinese suppliers to MD-80 aircraft in U.S. service.

Meanwhile, Indonesia's state-owned aircraft manufacturer, PT Industries Pesawat Terbang Nusantara (IPTN), has the largest and most developed facilities for aircraft design and production in Southeast Asia. Indonesia has targeted aeronautics as a strategic industry and has dedicated large resources to develop the capability to domestically design and manufacture entire commercial aircraft to serve the Asian region. And unlike other Asian countries, Indonesia designs and manufactures its own aircraft, usually in joint ventures with various international aerospace giants.

IPTN was established in 1979 as a joint venture with the Spanish aircraft manufacturer CASA to assemble light planes and helicopters. Later, it developed a 35-seat aircraft for domestic use. Its first wholly home designed and produced aircraft, a 50-passenger twin-engine turboprop, is expect-

At Samsung Aerospace Industries Ltd.'s facility in Changwon, an industrial town on the south coast of South Korea, workers prepare for an engine test. The firm produces the PW 4000 engine for the Boeing 747 and other engines for the F-100, F-15, F-16, A-250, T-56, and 412SP military aircraft. Samsung also has joint venture operations with Pratt & Whitney Co. and General Electric Co.

ed to be put into commercial service in 1995. IPTN has also been awarded OEM contracts by Boeing, GE, Pratt & Whitney, and other U.S. manufacturers to supply parts and components for U.S. military and commercial aircraft.

Singapore, Malaysia, Indonesia, and Australia are capturing much of the business of overhauling and maintaining aircraft of all types. Wage rates near US \$20 per man hour, compared with \$40 for the United States and \$60 for Europe, make the depots among the largest and busiest in the world. These depots now provide some replacement parts of their own refurbishment or manufacture. The aims of these countries are the same as those of the Japanese, South Korean, and Taiwanese military and commercial aircraft programs: development of an industrial infrastructure, with special attention to building skilled-labor pools, and technology transfer, while looking toward future opportunities to assume larger roles in international aerospace markets.

STEALING A LONG MARCH. China as well as Japan is working its way toward becoming a major international provider of commercial satellite launch services. Its home-grown family of Long March expendable launch vehicles, hybrids of Soviet, Western, and Chinese technology, could take a big bite out of U.S. and European shares in the commercial launch business.

Last September, for example, the Chinese launched their own weather satellite, Fen Yun 1B. Fen Yun, which means "wind and cloud," is transmitting high-resolution, true-color images of the earth in a signal format compatible with the U.S. National Oceanic and Atmospheric Administration's NOAA/Tiros satellites. It was carried into orbit on Sept. 3 on a Long March 4 booster from the

new Jiuquan launch site southwest of Beijing.

Meanwhile China has begun design studies for a four-man space capsule that would be launched on the country's new Long March 2E heavy-lift booster. The 2E is essentially the Long March 2 enlarged with liquid-fueled strap-on boosters similar to those of the European Ariane rocket. The vehicle, first tested last July, can place 8800 kg payloads into low earth orbit.

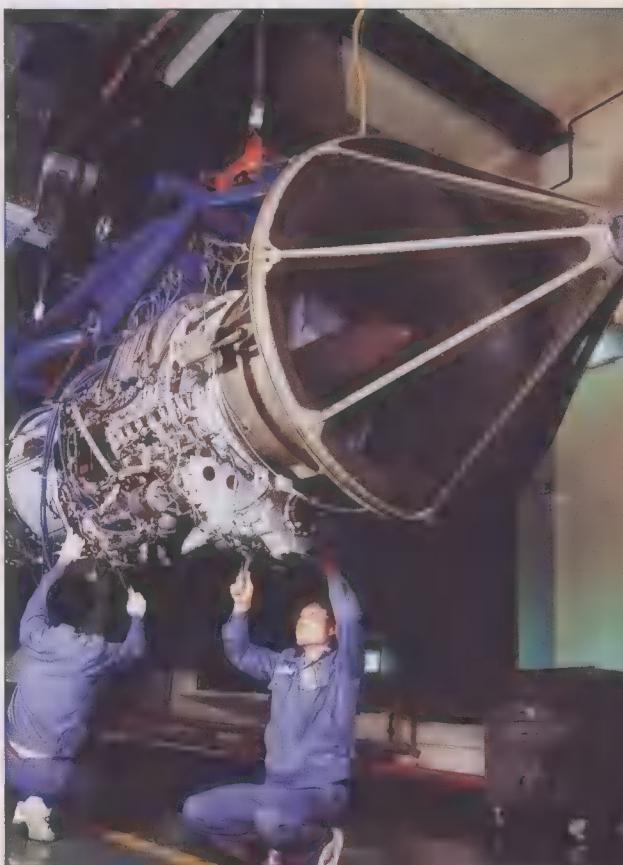
Last year China launched its first payload for a foreign customer, when a Long March 3 carried the former Westar 6 into geostationary transfer orbit. Rebuilt since its recovery by the U.S. space shuttle, the satellite is now owned by a Hong Kong-based consortium under the name of AsiaSat-1. The undisclosed price for the service, the subject of much speculation by the international launch service community, may have been as little as half the price of a comparable launch by Arianespace or one of the commercial U.S. companies in the business. Going rates for Long March launches may regularly undercut other commercial services by 20 percent, but technology transfer prohibitions may limit the number of spacecraft permitted to take the Long March route to space.

This cut-rate introductory launch may come back to haunt China and its Asian neighbors by changing their way of life. Asiasat's major shareholder, Hutchinson Whampoa Ltd. of Hong Kong, has announced its intentions to start direct television broadcasting to most of the Asian basin through its Hutchvision subsidiary [see "Telecommunications," p. 37].

JAPAN'S LAUNCHERS. Since launching its first orbital spacecraft in 1970, Japan has been progressively developing this space capability. Now, its own heavy-lift expendable launch

vehicle, the H-II, is the largest single development project for its National Space Development Agency (Nasda). The H-II is being designed to lift a 2-metric-ton communications satellite into a geostationary transfer orbit. The first launch attempt is expected in 1993; the development project, begun in 1984, now has a budget of 37.8 billion yen (US \$380 million).

The H-II's LE-7 liquid-hydrogen-liquid-oxygen main engine, essentially a smaller version of the U.S. space shuttle's main engines, profits from the knowledge and experience Japan gained through kit assembly and subsequent manufacturing of motors licensed from Rockwell International Corp.'s Rocketdyne Division. Like the shuttle main engines, the LE-7 motor has encountered technical problems during its development. Control software glitches, turbopump failures, and test stand fires, reminiscent of problems encountered during space shuttle



Samsung Aerospace Industries Ltd.

main engine development in the 1970s, have delayed launch by more than a year.

Nasda is also coordinating development of the Japanese Experiment Module (JEM), Japan's contribution to the proposed U.S. space station Freedom, and HOPE (H-II Orbiting Plane), a small shuttle-like reusable spaceplane. These projects, though in development simultaneously with the H-II, will likely follow it to expand its usefulness.

Troubled by the technical and bureaucratic difficulties encountered by the U.S. National Aeronautics and Space Agency's space station, Nasda has also commissioned feasibility studies examining the use of JEM-type modules and H-II lifters to orbit its own modest space station sometime after 2005.

Like its European and U.S. counterparts, Japan is also researching a single-stage-to-orbit aerospace plane, at its National Aerospace Laboratory. Much of the technology—fuselage, power plant, and structural and thermal-protection materials—is still being defined. By 1989, the budget was US \$35 million, and that is expected to double each year for the next several years. ♦

MEDICAL ELECTRONICS: emphasizing practical, low-cost equipment

Karen Fitzgerald Associate Editor

Apart from Japan, the Asian countries of the Pacific Rim have barely scratched the medical electronics field, and Japan's concentration has been on technologies like X-ray and ultrasound that are a few lengths back from the leading edge. But this may prove commercially shrewd, as products offering practicality and low cost, areas where Japan has focused its energies, become attractive to Western countries in the grip of an acute health care cost crisis.

That strategy has already paid off. From 1980 to 1990, Japan's portion of medical product imports to the United States, the world's biggest consumer, rose from 18 to 24 percent, while Germany's share dropped from 35 to 25 percent. The United States is still the world's major supplier of medical technology (exports increased from \$1.9 billion to \$6.5 billion in the 1980s), but U.S. as well as European manufacturers are increasingly embarking on joint ventures with Japanese medical manufacturers. These partnerships give them not only access to Japan's growing health care market, now second in the world, but also products that have created new markets in their own countries.

Among those deals, Philips NV of the Netherlands and Hitachi Ltd. began a joint venture to make computed tomography (CT) scanners, while Siemens AG linked with Asahi Chemical Industry Co. for CT and magnetic resonance imaging (MRI) products. Toshiba Corp., Japan's biggest medi-

cal manufacturer, bought the MRI division of California's Diasonics Inc. A joint venture begun in 1982 between Wisconsin's GE Medical Systems, a division of General Electric Co., and Tokyo's Yokogawa Electric Co. proved so fruitful that GE increased its ownership of Yokogawa Medical Systems stock from 51 to 75 percent in 1986.

The success of the GE-Yokogawa partnership arises from the different product focuses of the two companies. Japanese customers want compact systems, according to Al LeBlanc, recently retired vice president of Yokogawa Medical, because hospitals in the crowded country are small and in many cases, their construction is not adequate to support the huge MRI systems sold by Western companies.

Furthermore, insurance reimbursements in Japan for MRI and CT scans are only about a third of those in the United States. Consequently, Japanese products have to cost less and be cheaper to operate. Also, since medical malpractice suits are almost unheard of in Japan, doctors need not acquire top-of-the-line equipment just to protect themselves.

Yokogawa and other Japanese companies keep costs down by developing application-specific units, rather than the general-purpose instruments that Western companies favor. Japanese MRI users, for example, typically use a limited number of pulse sequences, which trigger the RF and magnetic field gradient sources that apply electromagnetic fields to the patient. Additional pulse sequences are needed to make more sophisticated measurements, such as MR angiography, which shows blood flow in vessels to diagnose narrowing or closing due to cholesterol buildup. With still more pulse sequences, measurements can image body function. Western hospitals, even when they do not need these alternative measurements, buy units that can be upgraded later if need be.

To accommodate additional pulse sequences, MRI machines must have more software and a larger power supply and cooling system. Japanese companies reduce costs by incorporating smaller power supplies and cooling systems, simpler software, and no coil shielding. Moreover, LeBlanc said, Japanese systems are designed for only a five-year life, since requirements change over time.

ULTRASOUND PROWESS. Ultrasound is just now making a comeback in the United States and Europe with the development of miniature probes that can be inserted into body cavities and even arteries. In contrast, the Japanese have always been enamored of ultrasound and over the past decade have steadily expanded its application as well as reduced its cost. As a result, Japanese physicians now use it as routinely as a stethoscope; rather than sending a patient for a CT or MRI scan a week or more later, Japanese doctors prefer to take a quick look right in the office with ultrasound.

Japanese manufacturers Toshiba Corp. and Aloka Co. lead the ultrasound field. Their products have more channels and better memory than Western products for the same price. They typically have as much computing power as a CT scanner, and incorporate the latest ultrasound capability—color flow Doppler, which can image blood flow as effectively and much less expensively than MR angiography.

Other areas of Japanese expertise revolve around health care for the elderly. The aged segment of Japan's population is growing faster than that of any other nationality. By the year 2020, it is estimated that 25 percent of the population will be over 65. The Government's Ministry of International Trade and Industry (MITI) is funding medical research on monitoring systems, like blood pressure alarms, and miniaturized instruments, like handheld electrocardiographs, that can be used by the elderly in the home.

Biosensors have stirred more interest in Japan than in the West because the Japanese believe they will significantly improve the quality of life. Combining electronics and organic matter that can detect chemicals and biological substances, biosensors are being applied in the chemical, food, and environmental industries, as well as in medicine. Sensors that detect glucose are already on the market, and researchers hope to miniaturize them and fit them onto an IC chip that could operate continuously in diabetics, with a micropump to inject insulin on demand. In development are sensors for alcohol, immunoglobulin E (for allergy diagnosis), and antigens that indicate the presence of a tumor.

Because of the frequency of neurological problems like hypertension and cerebral stroke in Japan, much research is devoted to the brain. Last year MITI formed a US \$44 million consortium with nine Japanese companies to develop a biomagnetometer,

Top Pacific-Asian makers of medical diagnostic gear

Company and country	Product made in-house
Toshiba Corp. Japan	Full diagnostic line*
Hitachi Ltd. Japan	Full diagnostic line
Shimadzu Corp. Japan	Full diagnostic line
Yokogawa Medical Systems Ltd. Japan	Computed tomography, magnetic resonance imaging, ultrasound
Siemens-Asahi Medical Systems Japan	Magnetic resonance imaging
Aloka Co. Japan	Ultrasound

*X-ray, computed tomography, magnetic resonance imaging, ultrasound, and nuclear medicine.

Source: Japan Industries Association of Radiation Apparatus

a noninvasive device for detecting faint magnetic fields from the brain, according to Nagaaki Ohshima, a professor in the imaging science and engineering laboratory of the Tokyo Institute of Technology.

It is hoped that such instruments, recently approved by the U.S. Food and Drug Administration, may help with problems like Alzheimer's disease and schizophrenia. They have already been used to locate epileptic foci in the brain when the treatment for epilepsy involves removal of brain tissue. Current systems have 37 sensors, but the Japanese hope to develop a 200-sensor system that will give more than five times the existing resolution.

South Korea will probably be the next focus of medical electronics activity in East Asia. Though China and Taiwan are bigger exporters of medical products, these are chiefly low-tech items like surgical instruments and supplies. GE has a joint venture with Korea's Samsung Electronics Co. to produce diagnostic products, and the company has also just begun ventures in China and India.

LeBlanc predicts that product trends in the East and West will meet at some point in the future. The United States and Europe will make more economical products, while Japan will add nonessentials and upgradability to its product lines. ♦

POWER & ENERGY: growing out promising technologies

Glenn Zorpette Senior Associate Editor

Electrification in East Asia ranges all over the map—both literally and figuratively. At one extreme, Japan's thriving heavy-electric-equipment industry is at least on a par with its European and U.S. counterparts, its utility industry boasts numerous capable design firms, and it runs a world-class program of electric power R&D.

Elsewhere, countries like Indonesia, Malaysia, the Philippines, Thailand, and Vietnam are still electrifying, with annual per capita rates of energy use ranging from about 100 to 1000 kilowatthours (Japan's rate in 1989 was 5680 kWh, which is not even considered particularly high among advanced nations).

Somewhere in between fall South Korea, Taiwan, Singapore, and Hong Kong. The Pacific Rim's four tigers have annual per-capita energy-use rates between 1850 kWh and 4500 kWh. But of the four, only Korea and Taiwan have indigenous equipment industries, and only in Korea and Hong Kong does electricity come predominantly from privately owned utilities.

In electricity production, two themes pervade the region: adding generating capacity to keep up with demand rising as fast

as 16 percent a year, and lessening a dependence on oil that is high in most East Asian countries.

Surging demand, coupled in some cases with outages at key generating plants, has dangerously eroded reserve margins in several Asian countries, including Japan, South Korea, and the Philippines, where utility officials are looking ahead to the com-

lations between the countries are improving, though, environmental concerns may create insurmountable obstacles.

Much of the rest of the region has nuclear plans, which vary in scope and in every case are the subject of modest but growing public opposition. The Daya Bay nuclear plant, under construction on the China coast 52 km from Hong Kong, is an example. A joint project by the Guangdong Nuclear Investment Co., a state-owned Chinese enterprise, and the China Light and Power Co., a Hong Kong utility, the plant will have two 900-MW units, with reactors from Paris-based Framatome and generators by GEC-Alsthom, Great Britain. Local environmental groups have expressed vague misgivings, but construction has proceeded apace.

In fact, Asia's Pacific Rim will in all probability be the proving ground for the next two generations of nuclear reactors from U.S., Japanese, and European companies. Japan's utilities hope to bring 40 new reactors on line by 2010, including General Electric's first two advanced boiling-water reactors in the mid-1990s ("Japan's nuclear power tightrope," *IEEE Spectrum*, April 1991, pp. 77-80). The company has links to Toshiba Corp. and Hitachi Ltd. for the design, testing, production, and sale of nuclear steam supply systems and other equipment. Mitsubishi Electric Corp. is paired with Westinghouse Electric Corp. for much the same purposes.

South Korea, where two nuclear plants are under construction at Yonggwang, has expressed interest in another advanced reactor, ABB/Combustion Engineering's System 80+, a pressurized-water design.

Engineers from Indonesia, which operates no commercial-power reactors at present, have visited Westinghouse's Pittsburgh headquarters for briefings on the company's AP-600, a simplified reactor design incorporating passive safety features (this reactor type is considered the likely successor to the advanced models).

GIANTS RULE. Japan's electric-equipment manufacturers include several of the country's diversified giants: Hitachi, Toshiba, Mitsubishi Electric, and Fuji Electric. These four have annual revenues ranging from about US \$5 billion (Fuji) to about US \$50 billion (Hitachi). Heavy power equipment—turbines, steam supply systems, transformers, switchgear, and the like—typically accounts for roughly one-fifth of their sales (except for Fuji, which derives about a third of its sales from this sector).

Korea's main heavy equipment makers are Leechun Electric Manufacturing, Goldstar Instrument & Electric, Hyosung Industries, and Hyundai Electrical Engineering. All of them make transformers, switchgear, and circuit breakers. Leechun also manufactures generators and capacitors, and Hyundai, generators and power-electronics systems. Smaller electrical manufacturers in Korea include Kukje Machinery, Cheil Electric Wir-

Asia will provide the next proving grounds for nuclear reactors

ing summer peaks with some trepidation.

Nearly all of Singapore's electricity is oil fired, as is about 30 percent of Japan's. Indonesia, with about two-thirds of its capacity oil-fired, has the region's largest domestic oil supply, followed by Malaysia and the Philippines. Sizeable reserves appear to exist off the coast of Vietnam, but these have not been extensively exploited yet.

Thailand, with deposits of lignite in the southern part of the country, plans to use this low-quality coal in several new or expanded generating plants planned for the next decade.

Malaysia's effort to cut its oil dependence to 40 percent by the year 2000 has been set back by the embarrassing disclosure last February of apparent improprieties in the purchase of seven gas turbines from ABB Asea Brown Boveri Ltd., the Swedish-Swiss giant. A group of engineers at Malaysia's state-run utility, Tenaga Nasional, protested the utility's decision to pay US \$370 million for the turbines—nearly twice what Korea Electric Power Corp. agreed to pay at about the same time for a more powerful set of gas turbines from General Electric Co. in the United States. The revelation prompted an inquiry by the Malaysian parliament into the purchase and related allegations of poor planning, maintenance, and repairs at Tenaga.

Renewable sources are also being pursued. The existing eight geothermal plants in the Philippines can provide almost 20 percent of demand, and 13 more plants are planned or under construction. Taiwan expects to finish constructing a 106-MW hydro plant next December and a 1600-MW pumped-storage plant in 1993.

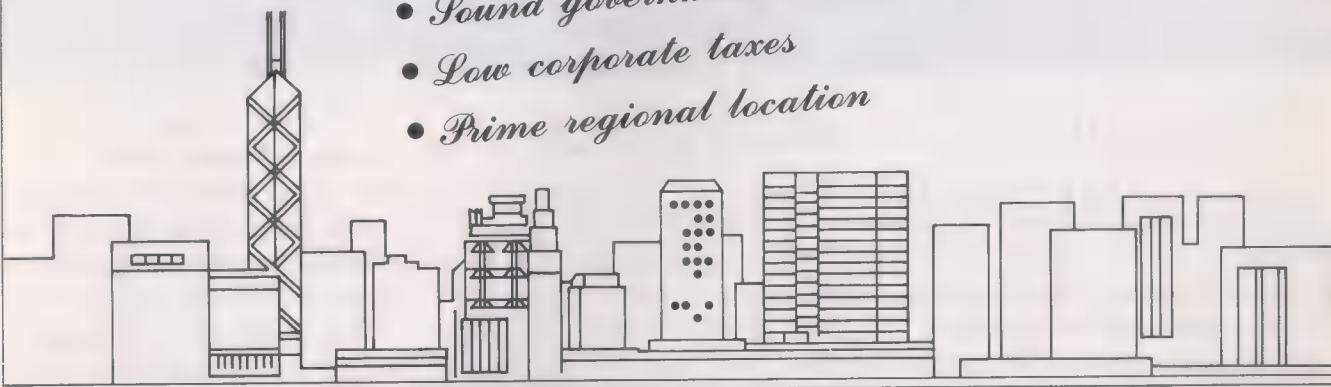
AMAZON OF THE ORIENT. Hopes have also risen in some quarters for regional hydroelectric development on the Mekong River. The so-called Amazon of the Orient—flowing through China, Laos, Thailand, Cambodia, and Vietnam—could easily generate 24 200 MW, according to past development plans. Poverty and military conflict have for four decades deferred development, other than for a handful of relatively small projects on tributaries. Now that re-

Six hundred overseas companies have nearly US\$4 billion invested in manufacturing in Hong Kong.



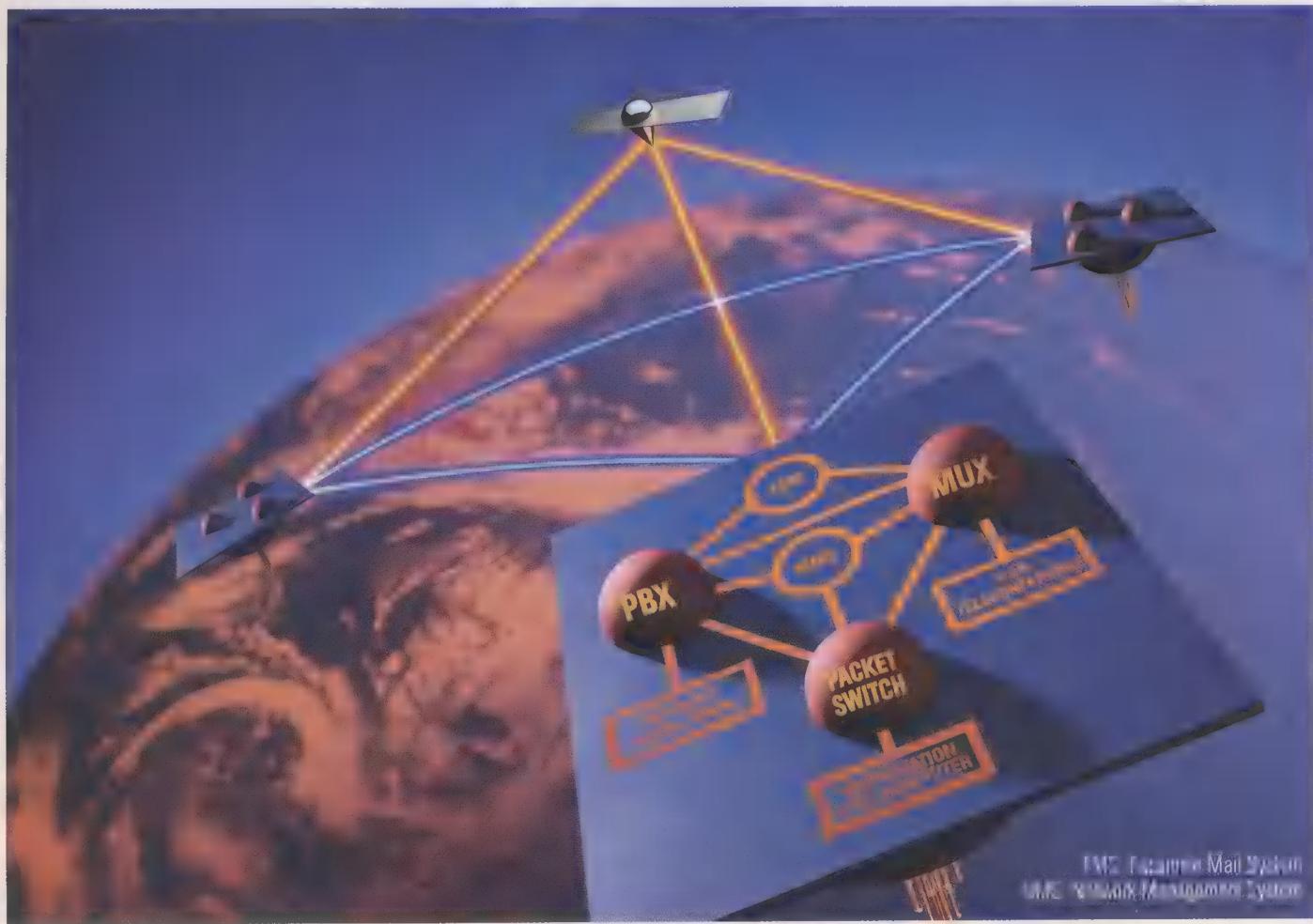
Here are just some of the reasons they gave:

- Excellent banking and financial facilities
- Supportive infrastructure
- Productive workforce
- Favourable business laws and regulations
- Sound government economic policies
- Low corporate taxes
- Prime regional location



FAX for more information about manufacturing in Hong Kong: Hong Kong—Sarah Kwok (852) 730-4633; Tokyo—Yoshihara Nishikawa (33) 446-8126; New York—Lawrence Chan, (212) 974-3209; San Francisco—Patrick Chung (415) 421-0646; Brussels—John White (02) 640-6655; London—Donald Fletcher (071) 493-1964

NEC NEWSCOPE



FMS Facsimile Mail System
VMS Network Management System

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NEC provides total support for network construction. Our services range from problem analysis to system design, installation and maintenance.

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The goal of worldwide telecommunications is free exchange of information throughout the global community. But North America, Europe and Japan all have different digital communication standards, and the digital networks of the nations involved cannot freely interconnect.

The network node interface (NNI) operating in the synchronous digital hierarchy (SDH) offers a clear solution. SDH is recommended by CCITT/CCIR and sets an international standard for high-speed digital transmission. SDH is the key to flexible broadband networks that feature efficient operation, administration and maintenance.

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FOTS and digital radios with NNI are already in commercial service in Japan. FOTS based on SONET (the U.S. version of NNI) have been on field trial in the U.S. since 1990. SONET digital radios will go on trial this year in Australia and the U.S.

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The NEC Super Tower, our new 180m, 43-story skyscraper in Tokyo, is a living model for next-generation smart buildings. The tower provides a comfortable environment for 6,000 headquarters personnel and supports them with integrated communications, information processing and television systems.

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Super Aladdin links seven distributed power servers with workstations or 2,000 PCs in a LAN.

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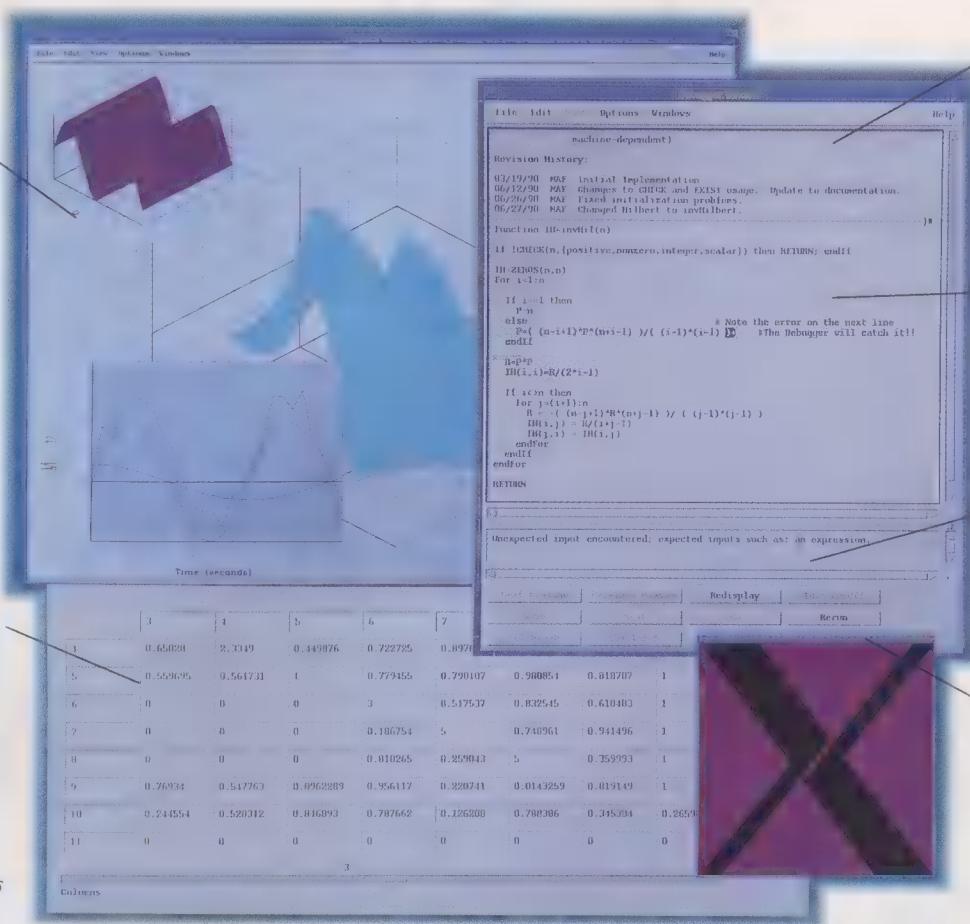
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ing Devices, Chang-An Industrial, and Shinill Electric.

Taiwan's largest equipment maker, Shihlin Electric & Engineering Corp., produces circuit breakers, capacitors, transformers, and other equipment, and is partly owned by Mitsubishi. There are also several sizable wire and cable makers in Taiwan, including the Pacific Electric Wire & Cable Co.

National programs of electric power research and development in East Asia are much as might be expected: extensive in Japan, moderate in Korea, just getting under way in Taiwan, and nonexistent elsewhere.

Key research thrusts in Japan include advanced battery storage systems, fuel cells, heat pumps, ceramic gas turbines, and applications of superconductivity. The Ministry of International Trade and Industry (MITI) sets the main research directions, with the assistance of the country's electric utilities.

Major utilities, equipment manufacturers, and several other Government or quasi-Government organizations also support and perform research. This latter group includes the New Energy and Industrial Technology Development Organization (NEDO), the Central Research Institute of Electric Power Industry, the Electric Power Development Co., and the Science and Technology Agency.

The South Korean Government sponsors most electric power R&D in that country through the Ministry of Science and Technology, the Ministry of Trade and Industry, and the recently privatized national utility, Korea Electric Power Corp. The key offices within these organizations are, respectively, the Korea Electric Research Institute, the Industrial Information Research Institute, and the Electric Research Institute. The utility also supports a Basic Electric Power Research Center at Seoul National University. Major research thrusts include investigations of ceramics, metals, and other high-tech materials.

Taipower, Taiwan's national utility, has stepped up its internal research activities in recent years, and now spends 1 percent of its gross sales on R&D. ♦

TRANSPORTATION: maglev rail, subways

Dennis L. DiMaria Associate Editor

Sprawled over more than 60 degrees of latitude and 45 degrees of longitude, Asia's Pacific Rim is a prime market for air, land, and water transportation. It has a broad mix, from bicycles and motor scooters to bullet trains and jumbo jets. Often, lugsaile junks adorn the same rivers that flow past congested, modern ports with bustling wharves.

East Asia has led in rail technology ever since 1964, when Japan's bullet train introduced high-speed rail transit to the world.

The Shinkansen sped over the Tokaido line linking Tokyo and Osaka. Currently, 600 000-plus passengers a day are hurled at speeds up to 275 km/h over four lines. France's Train à Grande Vitesse (TGV) now holds the world's speed record, set in May 1990 with a run of 515.3 km/h. But Japanese companies hope to boost the Shinkansen's record of 325.7 km/h, set last Feb. 28, to 350 or 400 km/h within five years.

One hope for a breakthrough centers on magnetic levitation. Japan Railways has run prototypes at about 500 km/h. Resting on ordinary wheels, the maglev train is lifted about 10 cm by the repelling force of superconducting magnets once a speed of 42 km/h is reached. The track contains a linear synchronous motor to propel the car forward.

Perhaps closest to actual operation is a project of the High Speed Surface Transport Corp., Tokyo. A prototype funded by Japan Airlines reached 318 km/h on a test track. For propulsion it uses a linear induction motor located in the car and for levitation, conventional magnets in the lower part of the frame. The system has been certified for operation in Japan; a 200-km/h version may be built in Las Vegas in the United States, pending approval by the state and local governments.

In South Korea, where most of the long-distance rail system predates World War II, the Government wants to build a US \$8.3 billion, 450-km, high-speed rail system from the capital, Seoul, to the main port of Pusan. Organizations that developed the French TGV, the Japanese Shinkansen, and the German Intercontinental Express (ICE) are expected to bid on this project. Also under consideration is a 200-km railway from Seoul to the east coast.

Taiwan, the other Asian tiger with a sizable territory, also plans a bullet train, linking Taipei in the north with Kaohsiung in the south at speeds of 300 km/h. Construction of the 353-km project is to begin by year's end and be completed in 1998.

FOUR SUBWAY SYSTEMS. Japan and the four tigers have overcrowded capitals, and four of the five boast modern subway systems. Tokyo's 220-km system, with 207 stations, is the most extensive of eight in major Japanese cities. In Korea, both Seoul and Pusan have modern subways, and construction in Seoul will more than double its 123-km system.

Every working day in Hong Kong, 2 million passengers pour through a system of 38 stations linked by 43.2 km of track. The network is mostly underground and, like its newer counterparts elsewhere, boasts automatic ticketing machines and electronically operated barriers.

On an average day Singapore's 67-km, US \$5 billion, rapid-mass-transit system shuttles 550 000 passengers through 42 sta-

Far Eastern air traffic forecast*

Country	Forecast traffic volumes, thousands		Average annual rate of growth, 1990 to 1994
	1990	1994	
Japan	31 532.4	44 736.7	9.5%
South Korea	9 620.6	15 168.3	12.6%
Taiwan	9 638.4	14 257.0	10.7%
Singapore	13 848.8	18 417.9	7.6%
Hong Kong	17 413.8	23 593.6	8.2%

*International scheduled passenger forecast of September 1990.

Source: International Air Transport Association (IATA)

tions. Residents may also travel by the Malaysian Railway to that country. Taiwan has no subway, but is installing an overhead light rail system to be operational in Taipei in 1993.

IN THE AIR. Japan, with the largest economy, has the largest airline complex. Four international carriers and four domestic airlines offer scheduled service. The biggest, All Nippon Airways Co., ranks eighth in the world in number of domestic and international passengers carried. But Japan Airlines Co. is the nation's largest international carrier, ranked 11th or 12th in the world. It is also one of the world's top three freight carriers.

The growth in air traffic in the years ahead will be so explosive that the International Air Transport Association has expressed concern whether East Asia's airports can expand fast enough to keep pace [see table, p. 48]. Japan and the four tigers all have expansion programs, six in Japan alone. One of the largest is Osaka's Kansai International Airport, a 1 trillion yen (US \$74 billion) project. Landfill complications have pushed back its completion date a year to 1994.

Tokyo's two airports, Narita and Haneda, now operating close to their limits, are earmarked for expansion. For 1995 completion, an 880 million yen project will enlarge Haneda's capacity by one-fourth to 230 000 landings and departures yearly. To nearly double Narita's capacity, land will have to be bought, a prospect certain to stir local opposition.

Hong Kong, served by about 40 foreign carriers at Kai Tak International Airport, projects that its single runway will exceed capacity by 1994. The Government has proposed a two-runway airport on Chek Lap Kok Island, but the project has been mired in controversy. China, which assumes jurisdiction over Hong Kong in 1997, views the project as redundant since it is building two airports nearby.

Korea has international airports in each of three major cities, Seoul, Pusan, and Cheju, and is constructing a fourth, to be Seoul's largest, on Yongjondong Island. Singapore, whose Changi International Airport is one of the most efficient, recently added a terminal there and plans others. Likewise, Taiwan's Chiang Kai-Shek International Airport, which last year saw traffic rise 15 percent, is building another terminal. ♦

Where East Asia Is ahead or behind

Technology	East Asia ahead	East Asia behind
Consumer	Neuro-fuzzy logic applications Variety of products demonstrated in Japan, including camcorders, washing machines, and air conditioners; neuro-fuzzy products embody a combination of fuzzy logic and neural networks for improved control	—
	Flat-panel color displays Active-matrix displays in production in Japan	—
	High-definition television (HDTV) Japan leads in analog satellite transmission systems	Digital terrestrial transmission systems
Integrated circuits	Dynamic RAMs 64M-bit prototypes from Japan; large share of world market for 4M-bit chips belongs to Japan and South Korea; dominance of 16M-bit market, now sampling, is likely	—
	Static RAMs 4M-bit prototypes from Japan; Japan and South Korea have large share of world market for 1M-bit size	—
	Microprocessors —	Design of high-performance 32- and 64-bit microprocessors
	Lithography Japan appears to lead in phase-shifted, X-ray, and electron-beam technologies	—
Computers	Digital signal processing —	Behind United States in special-purpose ICs
	Supercomputers Faster supercomputers with individual processors are being produced in Japan	Multiprocessor supercomputer systems
	Personal computers Many modules and subassemblies for U.S.-designed PCs and laptops produced in East Asia	Non-Asian-designed PCs still most numerous
	Peripherals Optical drives, high-density floppy-disk drives, and display technologies produced in Japan	Design of 2.5-, 3.5-inch hard-disk drives
Industrial	Software Reuse of existing code widely practiced in Japan in so-called software factories, noted for their improved quality (fewer bugs) and higher productivity	Standardized and application software (database management, communications, all PC-related software packages); operating systems, computer-aided software engineering, parallel processing, and digital signal processing
	Assembly robots Japan leads in design, production, and application of robots in industry	—
	Machine vision Japan leads in printed-circuit board and component assembly applications	X-ray laminography for checking solder joints
	Numerical control Japan leads in computerized numerical control	—
Telecommunications	Digitized and telephone networks Hong Kong and Singapore lead in the percentage of switches and lines digitized; Japan projects that its phone system will be 80 percent converted to Integrated-services digital network (ISDN) by 1995	Lack of basic telephone service in vast parts of Asia
	Cellular telephony Pocket cellular telephones in Japan; Hong Kong expects to offer the CT-2 Telepoint cellular payphone service by the end of the year	Lack of adequate switches and infrastructure in Taiwan and Thailand
	Satellite communications Japan offered first commercial high-power 12/14-GHz direct-broadcast satellite TV	Some of the satellite technology still based on U.S. and European design
Space/military	Military aircraft, missiles, and jet engines —	Most based on U.S. and European design
	Tilt wing, vertical short take-off and landing (VSTOL) —	United States leads with V22 developmental vehicle
	Manned space flight —	No man-rated launch vehicles yet in operation, although astronauts are in training in Japan
Medical	Ultrasound imaging Japan leads in low-cost, high-resolution systems with more computing power	—
	Magnetic resonance imaging Japan leads in simpler, low-cost systems	Behind the United States and Europe in high magnetic flux density (above 1.0 tesla) and scanning speeds
Power and energy	Power electronics Japan leads in high-efficiency inverter systems, gate-turnoff thyristors with high blocking voltage	—
	Nuclear power Japan leads in seismic testing and protection of nuclear plants	Japanese reactors still based on U.S. designs
	Combined-cycle turbines —	U.S., European designs ahead in higher efficiencies
Transport	High-speed trains —	Speed record of 515.3 km/h held by France
	Automotive electronics Japan leads in four-wheel steering, active suspensions, navigation systems, and fuzzy antilock braking systems and transmission controls	—

Source: IEEE Spectrum staff assessments

Formula for competitiveness

Strong government support, national technical objectives, dynamic science and technology centers, and robust educational institutions are key

The countries of Asia's Pacific Rim took diverse approaches to competing successfully in the electronics marketplace [see article below]. Government usually played a strong role in guiding development and establishing the appropriate business environment [p. 53]. And government also helped set up science parks and research institutes [p. 57], as well as provide education and training for the workforce [p. 59].

HOW COUNTRIES COMPETE: teamwork on a national scale

Alfred Rosenblatt Technical Editor
Tekla S. Perry Senior Editor

No one formula exists for the success in electronics enjoyed by Japan and the four tigers, though government support may be the most common factor. Certainly, Japan's climb from the devastation of World War II to one of the top technological powers today is the wonder of the globe. Critical to that success was the hard work of its people, but so was a national strategy for economic growth that the Government and industry hammered out together. The key to that success was trade with the world.

Some three decades ago electronics was recognized as an industry likely to generate a cornucopia of products that could provide a healthy industrial climate. But what was needed was access to technology Japan as yet lacked.

"The government orchestrated the acquisition and internal diffusion of foreign technology into its nascent high-technology industries," points out a study, *The development of high technology in the Asia Pacific region*, commissioned by KPMG, an accounting and consulting company in Chicago. "At the same time, it protected the

domestic markets from foreign competition."

The Government made sure that new technology went not to one company alone, but to several companies, each capable of becoming a strong competitor in Japan's home market. Through licensing agreements with foreign partners, the Japanese could speed up new product development while allocating limited R&D resources for the best effect.

The Japanese also worked hard at improving their base of technology. In the early '70s the Government took a very active role, spearheaded by the Ministry of International Trade and Industry (MITI), in fostering the development of key areas of electronics. The MITI model is being followed by other countries, including South Korea [“How governments help: MITI and its clones,” p. 53].

HIGH VOLUME, LOW COST. Many Japanese companies concentrated on high-volume products like semiconductors and consumer electronics; as volume increased, manufacturing techniques improved and costs fell. Some firms sought out neglected niche markets. Fanuc Ltd., for example, concentrated on industrial robots and numerical control. The Japanese became masters at making incremental improvements in design and manufacturing processes that would lead to ever higher quality. Quality—and satisfying the customer—became paramount.

Furthermore, consumer electronic product lines were always evolving, kindling new interest among potential customers. Fresh models sporting new features and improvements were continually brought to market, and older models discontinued. Always, R&D was a priority supported by the market leaders with a high percentage of sales.

Japanese manufacturers slugged it out in the domestic market, which the Government protected from foreign competitors. Only the best products and the most efficient manufacturers survived. A company's success in Japan indicated its chance of triumphing elsewhere. In fact, learning to compete effectively against Japanese manufacturers is an important reason analysts cite for foreign firms to sell in Japan.

But there is another reason for gaining access there. The high prices charged in Japan's protected market subsidized its manufacturers' attempts to carve out markets overseas. Instead of immediate profits, the goal is market share. The result has led to charges of dumping, or selling below cost or below what is charged elsewhere.

High retail prices and predictable component costs have been maintained in Japan, in part by an inefficient distribution system and because of what is now called the *keiretsu* system. Having roots dating back a hundred years, a *keiretsu* is a group of companies that own shares in and do business with each other. There are eight major groups—each comprising maybe hundreds of firms ranging from general trading to banking to manufacturing to chemicals processing [see top chart, p. 52].

SELF-SUPPORT. The companies work together, supporting each other technically, managerially, and financially. Japanese industrial customers tend to buy from their *keiretsu* partners first, then from other Japanese—groups of suppliers are linked to manufacturers within the *keiretsu* groups—and finally from outsiders.

Until recently, more than half the retail sales of electronics manufacturers within Japan were made by stores belonging to *keiretsus*. Matsushita Electric Industrial Co., for example, has 25 000 *keiretsu* retail shops; Toshiba Corp., 12 500. Through various arrangements with these outlets, including rebates and advertising subsidies, the manufacturers can maintain some control of retail prices and ensure high profits on domestic sales. Recent success in Japan of independent discount and chain stores, which do not offer the service arrangements included in the price of the *keiretsu* retailers, is loosening the hold of the *keiretsu* shops, however.

Japanese manufacturers also benefit from a lower lending rate than is available in western industrial societies. Of importance, too, is the willingness of Japanese investors—often the banks and companies belonging to the manufacturer's *keiretsu*—to receive a more modest return than are investors in the United States.

To lower costs, the Japanese, like their western counterparts, have moved some manufacturing offshore. In many cases, they have moved operations closer to their foreign customers, opening manufacturing plants and R&D facilities abroad. Locating facilities abroad also helps head off complaints about trade balances tipping heavily in Japan's favor, and the threat of protective tariffs. But as Japanese electronics companies have grown, so has the cost of expanding the business—new chip plants, for example, cost US \$350 million and up. Accordingly, recent years have seen a spate of alliances among giants of the industry.

"Where does a 700-pound gorilla sit?" the joke goes. "Anywhere it wants to." That is more or less true for South Korea's largest *chaebols*, the local word for group.

KOREA'S CHAEBOLS. These *chaebols* are modeled after the *zaibatsu* of Japan, which were dissolved after the war and reconfigured as bank-affiliated conglomerates, the *keiretsu*. The *chaebol* is typically controlled by a single family, which sets up a promising new business by itself, rather than seeking arrangements with smaller companies for parts or services.

The *chaebol* system sprang from government policies in the wake of the Korean War. A highly interventionist government, it granted monopolies to import products and enabled relatively few companies to obtain low-cost credit. It also selectively awarded companies opportunities to acquire formerly Japanese-held assets and to receive military contracts from its own defense department as well as from the U.S. government.

Companies with import licenses for highly desired products could parlay these businesses into large diversified conglomerates. Which companies got those early favors was based on political connections, pointed out Marcus Noland, assistant professor of economics at the University of Southern California (USC) and author of a study done for and published by the International Institute of Economics, *Pacific Basin Developing Countries: Prospects for the Future* (1990).

Concentrating resources in a few companies bred strong local competition and ensured that businesses grew large enough to compete internationally. In the 1970s, Noland told *IEEE Spectrum*, the Government sought to promote heavy industry, such as steel and chemicals, with subsidized loans and tax breaks. This further favored the established companies, reinforcing the *chaebol*. By 1980 the *chaebols*, now dominated by four groups—Samsung, Hyundai, Lucky-Goldstar, and Daewoo—were immense.

In the early 1980s, the Korean Government announced that developing a semiconductor memory industry was to become a national priority. It supported the nascent industry with subsidized loans and tax breaks and partially funded a cooperative research effort. The four largest *chaebols* moved into the semiconductor industry, with Hyundai and Samsung spending hundreds of millions of dollars to build component plants in South Korea and the United States.

For Hyundai, little experienced in electronics production, the worldwide semiconductor slump in the mid-1980s brought costly retrenchment and shutdown of its U.S. operation. Today, however, Hyundai's semiconductor business is steadily growing. But Samsung Electronics Co., which already had experience with watch chips and medium-scale ICs, found its foray into semiconductor memories a clear success.

Now, through its tested policies of low in-

terest rates and lowered taxes, the Korean Government is encouraging the electronics industry to develop semiconductor manufacturing equipment, Wan Hee Kim, a consultant in Sunnyvale, Calif., and publisher of the newsletter *Korean Technology*, told *Spectrum*. It reasons that the *chaebols*' aggregate billion-dollar annual equipment budget would be better spent within the country.

In the past year, the Korean Government also has announced policies to shackle the growth of the *chaebols* by restricting their access to loans while encouraging small and medium-sized companies. It has asked the *chaebols* to select three focal areas from among their many businesses on which to concentrate their resources, instead of scattering them in new and unrelated businesses—for example, land speculation. Only those three business areas selected by each will be exempt from a new credit control system.

The *chaebols* are also encountering internal pressures to reorganize; their rapid growth has left them too unwieldy to be family-managed, and companies are looking into reorganization as a means of distributing responsibility. Daewoo, for example, lost money in 1988 and 1989, sparking the sale of some divisions, group-wide fat trimming, and more effort at marketing its own brand-name products, in part through joint market-

Chinese settled in Taiwan in 1949, they confiscated land that had been held by the Japanese and the native Taiwanese elite, divided it into small parcels, and distributed it to peasants. Then to pacify the former Taiwanese landowners, the newcomers provided them with the financing to help them start manufacturing industries, said USC's Noland.

For years the country drew on its cheap labor to offer low manufacturing costs to foreign companies, and did little innovation, introducing textiles, footwear, toys, umbrellas, and other simple products. But, as has happened in all the Asian tigers, labor costs crept upward with prosperity—wage increases surpassed productivity increases for a few years—and it became clear that manufacturing alone could not sustain the economy.

When the Government began encouraging companies to go into high technology in the 1980s, it did not select only a few companies, but evenhandedly offered subsidized loans for investment in certain industries, tax incentives, and low-rent space in science parks. The Government also used various mechanisms to woo hundreds of Taiwan-born but U.S.-educated engineers and scientists back from abroad to start companies, Noland said.

One notable example is Morris Chang. In 1985 he was president and chief executive officer of General Instrument Corp. in the United States, following a successful career at Texas Instruments Inc. where he was senior vice president. In 1985 he returned to Taiwan as president of the Government's Industrial Technology Research Institute (ITRI). He now serves as ITRI's chairman, as well as chairman of Wyse Technology Inc. in the United States.

Because Taiwanese companies are small, alliances and unwritten agreements are critical. In particular, the companies joined with foreign original-equipment manufacturers (OEMs) to become current on products like personal computers, monitors, and calculators. One negative of supplying OEMs, however, is that the companies do not market directly to end users and so are not exposed to the vagaries of consumer taste.

Their diminutive size also means Taiwanese firms have little money to invest in R&D. Therefore, in order to seed some high-technology fields, the Government has to do something more than just supply financial incentives—it has to initiate technical development. That process is handled through ITRI.

Using ITRI as a catalyst, the Government boosted R&D spending to 1.2 percent of the gross national product (GNP) in 1988. During a six-year plan beginning this year, R&D spending is slated to rise to 2.2 percent of the GNP.

ITRI was instrumental in leading Taiwan's victorious foray into the computer industry,

Japanese manufacturers stayed it out in a market protected from foreign firms; only the fittest survived

ing ventures.

Further, through such joint ventures, Korean companies are also seeking technology, though their tendency toward domination and Korea's lax copyright laws have long inhibited such activity. More successfully, Hyundai and other Korean companies have set up joint ventures with technology transfer included to manufacture computer numerical controls with such companies as the United States' Allen Bradley Co. and Cincinnati Milacron Inc. and Germany's Siemens AG. As in Japan, companies doing business in Korea benefit from work weeks longer than the West's average—six days throughout Korea.

TAIWAN WOOS ITS EMIGRES. Taiwan's relatively tiny enterprises have little access to low-cost investment capital, so it is not surprising that a key high-technology target there is the personal computer business. It is highly entrepreneurial, fast-moving, and requires little up-front investment.

The tendency toward small companies, like Korea's inclination for monoliths, has historical roots. When mainland Nationalist

Asia's electronics leaders

Japan:*

Company	Electronics sales US \$ millions*	Total sales US \$ millions*	Electronics as a percent of total	R&D as a percent of sales	Employees in thousands
Matsushita Electric Industrial Co.	31 277	43 500	72	5.8	198.3
NEC Corp.	24 957	24 957	100	7.2	114.6
Hitachi Ltd.	22 209	51 290	43	6.1	290.8
Toshiba Corp.	21 722	30 812	71	6.3	142.0
Fujitsu Ltd.	18 478	18 478	100	11.7	115.0
Sony Corp.	16 904	20 870	81	5.7	95.6
Mitsubishi Electric Corp.	11 796	21 565	55	4.9	89.1
Canon Inc.	9 555	9 790	98	5.6	44.4
Sharp Corp.	7 943	9 746	82	5.9	34.0
Victor Co. of Japan	5 943	6 283	95	0.0	20.5
Sanyo Electric Co.	5 325	9 899	54	4.9	55.5
Ricoh Co.	5 010	6 050	83	6.0	N.A.

*For year ending in March 1990 except in the cases of Canon (year through December 1989) and Sanyo (year through November 1989).

1 Exchange rate: US \$1 = 138.0 yen.

Source: Elsevier Advanced Technology

South Korea:

Chaebo	1990 sales, US \$ billions	Main products and services
Samsung Group	43.4	Semiconductors, information systems, computers, consumer electronics
Hyundai Group	39.6	Automobiles, machinery, steel and metal products, shipbuilding, semiconductor ICs, computer hardware
Lucky-Goldstar Group	25.0	Semiconductors, computers and communications equipment, consumer electronics, electronic devices
Daewoo Group	16.0	Consumer electronics, home appliances, computers, components

Source: *Financial Times*, April 10, 1991; company reports and directories

Singapore:

Rank	Company	1989 sales, US \$ millions	Main products and services
1	Singapore Technologies Industrial Corp.	350	Computer systems, software, semiconductors
2	Wearnes Technology Pte. Ltd.	194	PCs, Winchester drives, floppy-disk drives, add-on cards
3	PCI Inc.	60	Printed-circuit boards, liquid-crystal displays, contract manufacturing
4	Eltech Electronics Pte. Ltd.	55	Contract manufacturing of industrial data communications equipment and computer-grade electronic assemblies
5	Goh Electronics Singapore (GES)	43	Manufacture of personal computers, computer assembly

Source: *Electronic Business Asia*, October 1990

Hong Kong:

Rank	Company	1989 sales, US \$ millions	Main products and services
1	Video Technology International Holdings	287	Computers, original-equipment manufacturer (OEM) products, and electronic games
2	Semi Tech Microelectronics (Far East) Ltd.	214	Retail and distribution, computers and other electronics
3	Wong's Industrial (Holdings) Ltd.	197.9	Printed-circuit boards, computers and OEM products
4	Tomei Industrial (Holdings) Ltd.	197.8	Consumer audio products and components
5	Conic Investment Co.	167.3	Electronics manufacturing, property investment

Source: *Electronic Business Asia*, July/August 1990

Taiwan:

Company	1990 sales, US \$ millions	Main products and services
Consumer Electronics		
Tatung Co.	1150	Household appliances, consumer electronics, computers, monitors
Industrial Components		
Sampo Corp.	537	Household appliances, computers, monitors
Personal Computers		
Acer Inc.	460	Computers, software distribution
Mitec International Corp.	188	Monitors and displays, integrated circuits
United Microelectronics Corp.	148	Memory chips, microcomputer ICs, consumer ICs
Automotive Electronics		
China Electric Ltd.	90	Lighting fixtures, lamps, electric bulbs

Source: Baring Securities Taiwan

earning Taiwan some 9.7 percent of today's world personal computer market. In 1985 the institute brought some 20 companies together to begin developing IBM-compatible personal computers. That effort simultaneously stimulated Taiwan's IC industry, with IC manufacturers like United Microelectronics Corp. and Taiwan Mask

Corp. among the tens of such manufacturers spinning off from ITRI.

Last year ITRI launched its biggest consortium so far—47 companies teamed with ITRI's Electronics Research and Service Organization (ERSO) to finance development of a notebook computer based on the Intel 386-SX. For the first time, such a con-

sorium went beyond the R&D stage to consider pricing and marketing.

Less than a quarter of the member companies will actually manufacture and market the notebook computers; the others will provide electronic components, plastic cases, and other parts. The group intends to save money on imported components—like the

386 chip from the United States and liquid-crystal display (LCD) panels from Japan—by bulk ordering. Now ITRI is trying to persuade several companies to join in developing the LCDs for notebook computers.

The Taiwanese Government, through ITRI, is also targeting submicrometer dynamic RAMs, high-definition television (particularly its niche component markets), integrated-services digital networks, and electro-optics for computer peripherals. [See table, p. 57.]

HONG KONG'S FREE ENTERPRISE. Unlike its competitors along the Asia-Pacific Rim, Hong Kong's entrepreneurs flourished with little Government assistance. Indeed, the British crown colony has been cited by U.S. economist Milton Friedman, the Nobel laureate, as a paragon of the free-enterprise system. Rather than guide technology, the colony's Government has through its basic fiscal policies molded an environment in which entrepreneurs can operate effectively.

This has produced some dramatic successes, like that of Paul Yau and Thomson Lam, who co-founded Porro Technologies. Now a division of the Paul & Thomson group, it manufactures its own brand-name workstations for export to Australia and the Pacific Rim. Yau and Lam also own motherboard-maker Inforntech International, and plan to start an R&D laboratory outside Hong Kong. Facsimile machines—Hong Kong was the first territory outside Japan to develop its own—as well as cordless telephones, small-screen color TV receivers, and other small apparatus have hatched other Hong Kong fortunes.

But in general, the assembly operations that dominate Hong Kong's electronics industry supply foreign OEMs with such things as watches and clocks, and circuit-board assemblies for telecommunications equipment, computers, and peripherals. The

Cooperation in Japan: three keiretsu

	Mitsubishi	Sumitomo	Dai-Ichi Kangyo
Trading	Mitsubishi	Sumitomo	C. Itoh & Co.
Bank	Mitsubishi Bank	Sumitomo Bank	Dai-Ichi Kangyo
Electrical manufacturer	Mitsubishi Electric	NEC	Fujitsu
Affiliated companies	Mitsubishi Heavy Industries Kirin Brewery Mitsubishi Motor NGK Insulators Chiyoda Chemical Honda Motor Okamura Kyosan Electric Japan Electron Ajinomoto Asahi Glass Ryobi Mitsubishi Chemical Nippon Kagaku	Kojima Sumitomo Chemical Sumitomo Metals Sumitomo Heavy Sumitomo Cement Sumitomo Bakelite Sumitomo Precision Sumitomo Forestry Sumitomo Construction Ando Electric Anritsu Electric Sumitomo Trust Sumitomo Realty Inabata & Co. Nippon Glass	Kawasaki Steel Furukawa Fuji Electric Nippon L. Metal Yasakawa Electric Niigata Engineering Kanematsu Gosho Shimizu Construction Iseki & Co. Meiji Milk Products Yokohama Rubber Asahi Denka Nippon Zeon Asahi Mutual

Source: James C. Morgan and J. Jeffrey Morgan, *Cracking the Japanese Market*, Free Press, New York, 1991, p. 40 (adapted with the authors' permission)

designs generally originate with the customers.

Complicating matters is an employee turnover rate of at least 15 percent. This figure is high in part because of uncertainty over Hong Kong's future once it comes under the sway of the People's Republic of China in 1997. Now that wages have risen to the point where Hong Kong is no longer competitive with countries like China, Malaysia, and Thailand for low-cost assembly, almost 90 percent of the colony's electronics manufacturers are farming out at least some production to the nearby Guangdong province of China.

Hong Kong businessmen may have more experience than any others in doing business in China. Eventually, this might translate into selling there as well. But for now their need is to move to more complex, higher-value-added products involving R&D. And since Hong Kong companies are on the small side—about three-quarters have fewer than 50 employees—they lack capital for R&D. Indeed, funds devoted to R&D are the lowest of all the tigers: 0.6 percent of the GNP.

SINGAPORE'S SPECIAL MIX. Perhaps in no country in Asia did the hand of government play a greater role in the success of its electronics industry than in Singapore. Mixing free enterprise with Government guidance and grants, Singapore has attracted multinational companies that have the cash and capacity for growth. Not only do the multinationals set up factories and provide employment, but they also have the international supply and distribution networks for worldwide sales. And, with them comes the technology transferable to indigenous engineers and would-be entrepreneurs.

In 1989 electronics output from the 633-

km² nation topped S \$24.26 billion, and the industry employed 115 800 people. This has been accomplished in the years since 1965, when Singapore became independent of Malaysia.

In 1965, Singapore's electronic operations were begun with a monochrome television assembly plant that produced TV sets for the local market. By the end of the decade the island's trade policy was oriented toward export, and the Government pursued multinational corporations. In 1969, several such companies established plants for assembling semiconductor components.

In addition, the Government—under Lee Kuan Yew, prime minister for 1959–90—introduced a series of measures to attract foreign investors. According to USC's Marcus Noland, these measures included lengthening the work week; reducing the number of holidays; restricting payment of retirement bonuses, paid leave, overtime, and bonus-

es in general; and exempting promotions, transfers, firings, and work assignments from collective bargaining.

The policies succeeded. Singapore became known as a place for low-cost assembly for export, largely of consumer electronics. By 1979, the output of electronics topped S 3.7 billion, having grown 30 percent in that year alone.

In short order, the industry developed from labor-intensive assembly to product engineering and automated assembly. More recently it has begun to perform IC design, wafer fabrication, and new product development.

The Science Council, set up in 1967, has no qualms about sponsoring R&D aimed at specific products. Thus, Singapore now is known for its capabilities in surface-mounting technology, and as a source for Winchester (hard-disk) drives, and it is also establishing itself as a center for computer services and software.

Some of the biggest companies in the world, including Hitachi, Siemens, Sony, Matsushita, Texas Instruments, Thomson CSF, Compaq Computer, Apple Computer, and Hewlett-Packard, have established factories in Singapore. Some even maintain R&D bases there to serve their global markets.

For example, Motorola Inc. and AT&T Consumer Products established R&D centers for communications equipment. AT&T's Bell Labs Singapore is the first such center to be established outside the United States. And Hewlett-Packard Co. maintains a center for industrial products such as computer keyboards and inkjet and thermal printers.

Locally owned companies also have R&D

Families of hundreds

Some Japanese groups	No. of subsidiaries
Hitachi Ltd.	688
C. Itoh & Co.	628
Mitsui & Co.	513
Mitsubishi Corp.	459
Honda Motor Co.	352
Matsushita Electric Industrial Co.	340
Sumitomo Corp.	287
Toshiba Corp.	215
Sony Corp.	163
Fujitsu Ltd.	152

Source: *Nihon Keizai Shimbun*, as cited in *The Economist*, Jan. 5, 1991

operations. Included are Chartered Microwave for microwave ICs, Essex for laptop computers, and Vikay for large-screen liquid-crystal displays. In 1989 the country was already equipped with a dozen IC design centers employing more than 100 design engineers, and yet other centers were being planned.

The Singapore Government is also now helping companies expand to two other regions—to Batam Island, Indonesia, 30 minutes away by ferry, and to Johore state, Malaysia, linked to Singapore by a causeway. The three are being called the “growth triangle,” with each region complementing the others in resources: Singapore provides technology, telecommunications, seaports and airports, and financing, while Batam and Johore supply the land, labor, water, and electric power.

HOW GOVERNMENT HELPS: MITI and its clones

Stuart M. Dambrot Correspondent

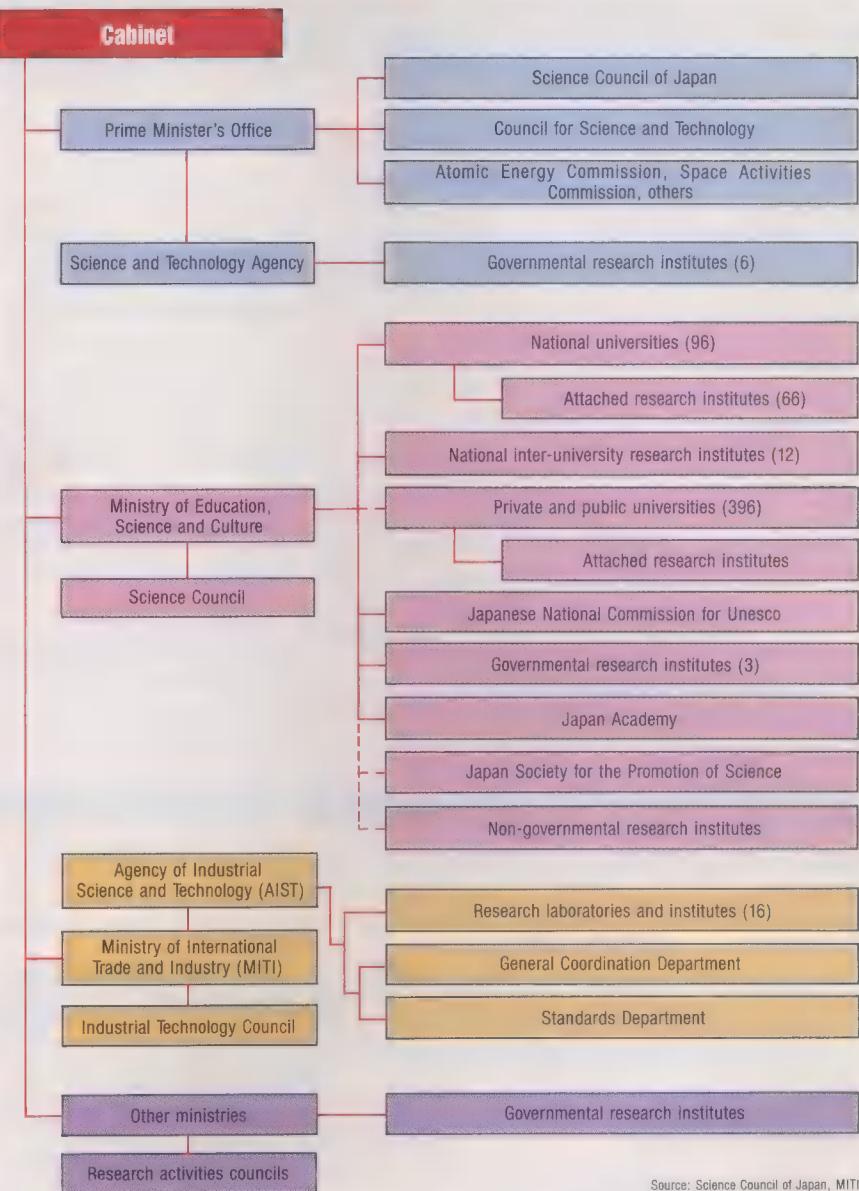
Japan's dramatic postwar recovery owes much to its Ministry of International Trade and Industry (MITI), which is well known for its role in shaping the country's business environment. Not surprisingly, neighboring countries are keen to emulate MITI's formulas for interacting with the private sector.

At the heart of this wish to mimic MITI are science and technology policy and development. After all, Japan's return to the world stage rests in part on the speed with which it has developed and marketed new product and process technologies and in part on import restrictions and highly competitive export pricing strategies. Because MITI has played a major role in all these areas, the MITI model of government-industry technology policy is coming to be viewed as a blueprint for rapid growth and international status.

JAPAN'S MITI MODEL. One of 25 Japanese Government ministries, MITI has a staff of 12,000 and a budget of 301.8 trillion yen (US \$2.2 trillion). It operates through a web of institutions [see chart]. These include its own Industrial Policy Bureau, in cooperation with other bureaus such as the one for machinery and information industries; its International Trade Policy Bureau; and for technology development programs, its Agency of Industrial Science and Technology (AIST).

AIST consists of a central bureau and 16 research institutes scattered throughout Japan. These institutes are engaged in a wide range of industrial technology R&D. The best-known is the Electrotechnical Laboratory (ETL) in Tsukuba northeast of Tokyo. All research done by the institutes ends up in the possession of AIST, which also promotes and funds multifarious projects.

MITI in relation to Japan's research establishment



Source: Science Council of Japan, MITI

The agency supports and promotes industrial technology development in a number of ways. These include conditional loans and guaranteed payments, tax incentives (co-authorized by the Ministry of Finance), financing (through the Japan Development Bank), research contracts in ETL-managed R&D projects, funding of joint research associates, and close connections with trade associations.

Since there is virtually no Japan venture capital industry, new business ventures are typically initiated by large firms and financed by closely linked corporate and banking interests. However, the Japan Key Technology Center—partially owned by MITI—provides capital investment and conditional interest-free loans for joint R&D ventures, among other activities.

Other offices also promote Government-sponsored technology research. These include six ministries and three agencies:

Science and Technology, Environment, and Defense. Nippon Telegraph & Telephone Corp. and the University of Tokyo have extensive R&D activities, too.

The Science and Technology Agency (STA), which is attached to the Prime Minister's Office and is AIST's main competitor for Ministry of Finance funding, formulates, implements, and coordinates basic science and technology policy. It also directly funds R&D programs. Comparing the two, Kunikatsu Takase, director of ETL's Research Planning Office, noted that “AIST's programs relate not only to science and technology, but to the industrial context as well. STA, while it covers many fields of science and technology, is involved with large projects that have less relevance for industry.”

One unique function of MITI has been to release a policy “vision” at the start of every decade since the 1960s. This is a general theme that, rather than specifying technol-

A sampling of government-supported R&D in East Asia

Project	Period	Funding	Goals	Results
Japan's MITI				
Superhigh-performance Electronic Computer Development	1966–71	10.1 billion yen	To kick off AIST's ongoing National Research and Development Program (R&D) on technologies important to Japan	A prototype system that, when commercialized by NEC, Hitachi, Fujitsu, and other firms—in combination with a "buy Japanese" edict from MITI—established Japan's domestic computer industry
New Energy Sources (Sunshine Project)	1974–	29.9 billion yen (fiscal 1991)	To study solar, geothermal, coal, hydrogen, wind, ocean, and biological energy sources, to limit dependency on imported energy	A variety of pilot plants, including coal liquefaction, a 100-kW wind turbine, and an alkaline-water electrolyzer
Very Large-Scale Integration (VLSI) Project	1976–80	US \$150 million	To extend optical microlithography to sub-micrometer levels and to develop new technologies for 16M- and 65M-bit memories	Significant advances in optical, electron-beam, and other microlithographic techniques and fabrication equipment that made Japan a leader in microelectronics
AI-Based Parallel Computer Architecture (Fifth-Generation Computer Project)	1982–March 1991	50.4 billion yen	To devise AI-based parallel-computing hardware and software, a project that put Japan on the advanced R&D map; MITI supported the project entirely, though some researchers were sent from academia and industry	Parallel-processing language and hardware (Mitsubishi Electric is selling a Personal Sequential Inference computer); the project has been extended three months to ensure prototype delivery
Software Productivity (Sigma Project)	1985–90	25 billion yen	To develop standardized, Unix-based software tools and productivity aids to combat a growing shortage of programmers and software engineers	Commercially available but expensive hardware and software, transformation of the project into a private company; however, the hardware still costs too much to gain widespread acceptance
Electric Automobile	1971–76	5.7 billion yen	To develop electric-powered vehicle prototypes to address oil dependency and city pollution	Several electric vehicles for urban use; but adequate battery life could not be achieved
Super/Hypersonic Transport Propulsion system	1989–96	3 billion yen	To devise a combined-cycle engine for sub- through hypersonic flight	R&D on ramjet, an advanced turbojet, begun; experimental models constructed; control system designed
South Korea's KIST				
Electronic Switching Systems	1960s	N.A.	To build a basic infrastructure	A telecommunications network that offers services (such as centrally switched call forwarding)
Super Alloy Project	1978–87	205 million won	To develop import substitutes in ultra-hard materials	Three U.S. patents awarded to KIST in 1989
Silicon Semiconductor Materials Project	1982–85	401 million won	To promote basic technologies in fledgling electronics industries	By the end of the project, import substitution worth US \$7 million annually of silicon-based materials
Freon Alternative Development	1982–87	119 million won	To develop substitutes for chlorofluorocarbons (CFCs), one of the earlier attempts	CFC substitutes, technology applicable to the refrigeration industry
Development of High-Quality VTR Magnetic Head	1986–90	235 million won	Having targeted consumer electronics markets in modeling itself on Japan, to start by pursuing the videotape recorder segment	Competitive video products, notably from Samsung and Goldstar; but market reaction has been restrained largely by consumer perception and loyalty to Japanese brands

ogies to be developed, throws the choice open to discussion with other Government agencies, manufacturers, consortia, and universities. MITI's vision for the 1990s was compiled by the Industrial Science and Technology Council and the Industrial Structure Council, advisory bodies that report directly to MITI's minister. Its focus is technological development in the context of internationalization, environmental concerns and Japan's standard of living.

SOUTH KOREA'S MTI. Korea's push into high-technology has for the most part duplicated its neighbor's. T.W. Kang, managing director of Global Synergy Associates, points out that the two countries' policy- and regulation-formulating ministries are highly analogous: Japan's MITI is mirrored by Korea's Ministry of Trade and Industry (MTI), for instance. There also are strong similarities between the two countries' economic policies, particularly in export orientation, eco-

nomic planning, and Government support for industry.

Kang acknowledges that disparities are appearing as Japan moves into more advanced technologies and increases its offshore manufacturing. He also notes that "such comparisons are relative," adding that "the similarities between Japan and Korea are far greater than those between Japan and other industrialized nations."

The Korean counterpart of AIST is the Korea Institute of Science and Technology (KIST). According to Oh Jong Nam, a visiting research fellow at the MITI-affiliated Institute of Developing Economies and director of Korea's Economic Planning Board, KIST's charter is to develop innovative technologies, conduct large national projects, carry out basic and applied R&D, and render R&D services. The institute, which has 11 research divisions and 55 laboratories, is affiliated with the Systems Engineering Re-

KEY:

- AI = artificial intelligence
- AIST = Agency for Industrial Science and Technology
- ATV = Advanced Television
- ITRI = Industrial Technology Research Institute
- KIST = Korea Institute of Science and Technology
- MITI = Ministry of International Trade and Industry
- N.A. = not available
- RDAS = Research and Development Assistance Scheme
- VTR = videotape recorder

search Institute and Genetic Engineering Research Institute.

Korea also has plunged 1.55 trillion won (US \$2.14 billion) into a five-year plan for technology development. The financing will be evenly shared by the Government and the

private sector. But the first year's increment is set at 10 percent of the total and consists wholly of Government contributions from the Korea Development Bank (62 billion won), MTI (55 billion won), and the Ministry of Communications and the Korea Electric Power Corp. (20 billion won each).

The Government has also identified 919 key technologies in 27 areas, chosen for intensive R&D by both the public and private sectors. Among the major groupings are optical fibers, telecommunications equipment, computers, semiconductors, other electronic components, and factory automation.

Despite such plans, Cha Dong-hoi, director of Lucky-Goldstar Research Institute, is doubtful of success. Cha, who puts Korea's high-tech level at "about four or five on a scale of 10," feels that "the Government will not live up to its promises." One reason for his skepticism concerns Korea's *chaebols*, giant conglomerates similar to Japan's pre-war *zaibatsu*. They have the money to carry out much of the necessary R&D; but the Government, in order to increase competitiveness, is trying to slow the *chaebols'* growth by limiting their access to loans. There is, however, talk of lifting the ceiling on the outstanding credit of the top 30 conglomerates, encouraging them to enter new areas of promise.

"You have to remember," said Oh, "that Korea's GNP is one-fifteenth that of Japan's, while the ratio of total R&D investment to GNP is roughly the same 2-3 percent as Japan's. Korea's R&D funding levels are therefore correspondingly smaller."

Taiwan's highly competitive atmosphere—described by C.S. Ho, chairman of the Taipei Computer Association, to "the Chinese entrepreneurial spirit"—supports a greater percentage of small businesses (under 200 employees and less than US \$20 million in annual sales) than does Japan. Many of these firms were started by "superstar" engineers, an unlikely occurrence in Japan, and manufacture just one product, such as keyboards, cables, monochrome monitors, power supplies, and controller chips.

Also gaining in popularity are development and marketing alliances between Government and industry. Last year, a consortium of 47 companies teamed with the Government-backed Electronics Research and Service Organization (ERSO) to develop a 386SX-based notebook PC. ERSO is a creature of the Industrial Technology Research Institute (ITRI). The entire development cycle lasted only four months. In a Japanese-style arrangement, the 47 firms, all of which paid some front money to join the alliance, will market their products separately.

As in Japan, the Taiwanese Government deserves much of the credit for the country's recent economic growth, especially in electronics. Reminiscent of MITI's 10-year visions, the Taiwanese Government has planned its economy in 10-year phases. This began in the 1950s with agriculture and targeted import substitution in the 1960s. In the 1970s, the Government set up enormous export-processing zones, while the 1980s saw Taiwan move into electronics and computers.

The theme for the 1990s is integration, said Irving Ho, director general of Hsinchu Science-Based Industrial Park. Even with the trend toward more Government involvement in aerospace, HDTV, and other advanced technologies, Ho said it will no longer suffice for Taiwanese companies "just to make and sell boxes"; they must add value. **TAIWAN'S ITRI.** ERSO and ITRI have a long history of joint development with the private sector. In March, ITRI announced six R&D focal areas for 1991: HDTV, aerospace, automobile engines, medical instruments, industrial waste and water treatment, and "critical electronic components" (memory devices and liquid-crystal display controller chip sets).

ITRI is Taiwan's version of Japan's AIST. It is a nonprofit organization with close links to the Taiwanese Government. In fiscal 1990 ITRI received about US \$163 million, or 61 percent of its financing, from the Ministry of Economic Affairs. The balance is earned from contracts based on technology spinoffs, many of which are located south of Taipei in Hsinchu Science Park, Taiwan's Silicon Valley.

ITRI is expanding its role in industrial technology development through a venture capital arm, the Taipei-based Industrial Technology Investment Corp. (ITI). Established to attract both Taiwanese and foreign investors, ITI is a counterpart of MITI's Japan Key Technology Center.

In semiconductor process technology, however, Taiwan still trails Japan and the West by as much as 20 years. Therefore, said

Project	Period	Funding	Goals	Results
Taiwan's ITRI				
Submicrometer	1990-	US \$220 million	To achieve submicrometer geometries by 1993 and 0.5 µm by 1995 (a continuation of the completed Microelectronics Project)	Responsibility for possible patent issues is provoking resistance from both Government and private sector
High-definition television (HDTV)	1990-	US \$192 million	To develop working prototype by 1995, using ATV standard being promoted in the United States (funding from Ministry of Economic Affairs)	No results to date
Sparcstation clones	1988-	N.A.	To license Sun Microsystems' Sparc chip for development	First complete workstation released by Tatung in 1990
Notebook computers	1990-	N.A.	To develop 80386SX notebook PC in a joint venture between ITRI and 47 companies	80386SX prototype completed in 1990—a different move for ITRI, which usually favors R&D above commercialization
Electro-optics	1985-	N.A.	To emphasize smaller, high-capacity drives (2-inch hard-disc, optical) and computer peripherals, and to build advanced laser printer engine by 1992	3.5-inch hard-disc drives and laser printer engines
Singapore's RDAS				
Robotic Transportation System	Fiscal 1988	US \$538 000	To develop system with help of Real Time Systems Pte. Ltd.	N.A.
Optical-Fiber Communication System	Fiscal 1988	US \$1 120 000	N.A.	N.A.
Compact Optical-Disc Storage Device	Fiscal 1988	US \$551 339	To develop the system with participation of Seagate Technology (Singapore) Pte. Ltd. and the National University of Singapore	N.A.
Microprocessor Applications Center	Fiscal 1988	US \$350 000	N.A.	N.A.
Machine Vision for Automated Inspection	In progress	N.A.	To develop the system through National Semiconductor Pte. Ltd. of Singapore	Used in GM Singapore Pte. Ltd.'s tape-pack placement machines

Source: MITI, AIST; KIST; ITRI; RDAS; Singapore's Economic Development Board

TCA's Ho, if Taiwan is to become a world-class competitor, "careful strategy" will be required such as promoting the vertical integration of production.

A second key consideration, Ho added, is resource integration. For example, he said, the Government has defined computers as one of Taiwan's strategic industries. Over the next 10 years it will spend US \$4 billion to implement a computer system linking the island's various governmental agencies and automate systems that, in Ho's words, "hearken back to the Stone Age." TCA has also proposed the development of a Software Industrial Park, which Ho said would be "a spinoff of Hsinchu."

SINGAPORE'S EDB. Singapore is a latecomer to R&D, having started in 1979. In that year the Government's Economic Restructuring Process formulated a long-term plan emphasizing R&D in 11 key areas. These included biotechnology, microelectronics, information technology, robotics and artificial intelligence, lasers and optoelectronics, and communications. Singapore's R&D spending is just ahead of Hong Kong's, but still lags behind that of the more populous Korea and Taiwan.

Vincent Yip, former executive director of the National Technology Science Board, acknowledges that the numbers of inventors and patent applications are quite low compared with the two latter countries. Nevertheless, observed Siew Hing Yun, one of the science board's directors, "the ratio of gross R&D expenditures to GNP increased from 0.3 percent in 1982 to 1 percent in 1989, and this is an encouraging factor."

The key difference between Singapore and the other tigers is that in this city-state businesses owned by foreigners—mostly U.S. companies—undertake many R&D projects. For the most part the businesses are courted by Singapore's Economic Development Board (EDB), which devises incentives to lure desired companies and implements the measures with consistent success. Liow Voon Keong, deputy director of the board's Components Division, noted that "in the 1960s, we actively sought out foreign companies, especially those in elec-

tronics, to provide jobs and technology. Many of these companies have remained with us, expanding their operations into new areas, such as R&D and production of high-tech, value-added products."

Currently, Singapore's long-term plans are the focus of R&D at the Institute of Molecular and Cell Biology, while short- to medium-term work is done by the Institute of Systems Science and the Information Technology Institute. The latter is the development arm of yet another active agency, the National Computer Board. In addition, a new institute of microelectronics was scheduled to begin operations in April. With Bill Chen,

policies support entrepreneurs, industry and academia now call for an atmosphere in which technology ventures prosper.

Why the concern? Hong Kong firms possess little R&D prowess, asserted Y.S. Cheung, sub (associate) dean in electrical and electronics engineering at the University of Hong Kong. "Local companies have no research ability," said Cheung. "Some do development work, but that's it."

To date, that approach has served for volume production of watches, telephones, and simple facsimile machines. However, competition is looming from other Asia-Pacific countries: Taiwan and Singapore threaten to overshadow Hong Kong in specialized products like hard disks, as well as in high-growth areas such as portable computers. In addition, two would-be tigers, Thailand and Malaysia, can undercut Hong Kong's production costs. A fresh approach to R&D relying on Government support, said experts, may well be the solution.

"The lesson we should learn from other countries is not how many billions of dollars they spent on developing R&D," said Robert Li, chairman of the Hong Kong Electronics Association at a symposium last November. "Rather, what contributes to their success is that they have a centralized body, heavily backed by government, to plan strategies and directions."

Recent months have been rife with prescriptions for Government involvement, although firm action has yet to be taken. A Government advisory committee headed by C.D. Tam, Motorola Inc.'s Hong Kong-based vice president, recommended that the Government establish a science park similar to those in Singapore and Taiwan. Tam and U.S.-based Dataquest Inc. also have developed recommendations for effective Government assistance to the local electronics industry. Other local businessmen have made their own suggestions.

Hong Kong Polytechnic's director, Poon Chung-kwong, wrote to the colony's governor, Sir David Wilson, about the latter's 1991 legislative calendar: "I am astonished not to find a single mention of the development of science and technology in your address. Like education, science and technology is a long-range effort."

The colony's six college-level institutions have gone beyond merely criticizing to jointly launching a campus-based consulting service intended to help industrialists identify opportunities in locally developed technologies. If well-received, the present participants will form a company that Chinese University vice chancellor Charles Kao said "can be linked with overseas experts...and which can serve as a think tank and a data bank for the private sector."

The Hong Kong Government has not completely ignored high technology. It funds R&D at the four institutions that offer post-graduate science and technology programs; has expressed interest in a science park,

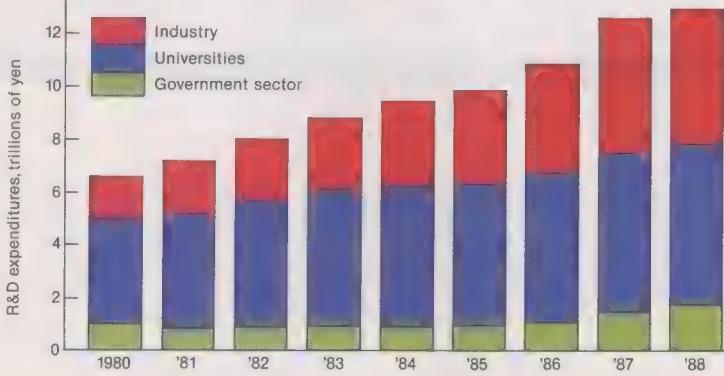
Taiwan, unlike Japan, has a sizable percentage of small businesses, many started by superstars'

director of AT&T's IC Customer Service Laboratory, at its head and the National University of Singapore heavily involved, the institute will focus on market-driven applied research. An institute of manufacturing technology is also scheduled to open this year.

A recently announced joint venture between the Economic Development Board and three private companies—the United States' Texas Instruments Inc. and Hewlett-Packard Co. and Japan's Canon Inc.—illustrates new interests on the part of the board. A Singapore-based company, TECH Semiconductor Singapore Pte. Ltd., will produce advanced dynamic-RAM chips based on submicrometer CMOS technology. The board and TI will each own 26 percent of the new venture, while Canon and HP will each have a 24 percent share. Construction of the new wafer fabrication facility is to begin by late summer with initial production expected in mid-1993.

HONG KONG COURSE CHANGES. Until recently, Hong Kong's approach to technology policy has been laissez-faire. Although fiscal

Japan's changing R&D mix, 1980-88



Source: Jetro, MITI, as cited in *Financial Times*, Dec. 5, 1990

possibly modeled after Tam's suggestion; is financing ■ HK \$2.28 million (US \$0.29 million) national study on automation; and has given the go-ahead to ■ HK \$200 million (US \$26 million) technology center that will serve as an incubator for small projects, mostly in information technology. In the meantime, private industry last year devoted US \$40 million to high-technology programs like software development and computer-aided design and manufacturing.

SCIENCE PARKS: intellectual talents create exports

Peter Gwynne Correspondent

The formulation could come from ■ chemistry textbook: bring together a critical mass of scientists, engineers, and technicians. Add Government funding. Put the team to work on several R&D problems in emerging technology. Wait a few years, and then start to collect the benefits, in the form of export earnings from the products and services developed through the teams' efforts.

And as in any exciting chemical experiment, the upshot is an explosion of science parks and research centers throughout Asia. Modeled on the United States' Route 128 in Massachusetts, Silicon Valley in California, and Research Triangle Park in North Carolina, these centers of leading-edge, high-technology endeavor are springing up on mainland and island alike.

Japan, inevitably, has led the way in developing such centers. Its Tsukuba Science City, 60 km from Tokyo, has become ■ mecca for pure and applied scientists in ■ variety of disciplines, and ■ huge Technopolis Project, started on Kyushu in 1983 with the goal of decentralizing the island nation's economy, just grows and grows. More recently, three of Asia's four tigers—South Korea, Taiwan, and Singapore—have adapted the broad concept to their own technology and trade environments. Even the fourth—Hong Kong, that laissez-faire maverick—is building a small technology center and preparing to launch a science park.

Meanwhile, tiger cubs and other nations that aspire to tigerhood are leaping on the bandwagon. In Bangalore, India boasts an "electronics city"; two new parks will soon open in the Philippines; and the city of Shanghai has an ambitious blueprint on the drawing board for a huge science, technology, and trade zone in its Pudong section. If successful, Pudong could restore some of the glitter Shanghai possessed in the 1930s.

RULES OF THE GAME. The successful Asia science centers obey a few basic precepts. Most important, it seems, is the proximity of strong institutions of higher education. That assures companies in the science parks of not only an astringent intellectual environment for their employees but also a supply

of well-trained graduates for entry-level jobs, as well as academic partners for collaborative research projects that can undertake the first steps towards new products.

Taiwan's Hsinchu Science-Based Industrial Park, for example, stands next door to the Industrial Technology Research Institute (ITRI), the National Tsing Hua University, and the National Chaio Tung University. The Singapore Science Park is associated with the National University of Singapore, the Nanyang Technological Institute, Singapore Polytechnic, and Ngee Ann Polytechnic. And Shanghai based hopes for its science park's development in part on the presence of the highly regarded Fudan, Jiao Tong, and Shanghai Science and Technology Universities.

Decentralized locations also appear to appeal to promising technology companies and the best and brightest employees. Taiwan's 4-km² Hsinchu, for example, stands in rolling countryside 90 km from the bustle and pollution of the capital, Taipei. Japan's Kumamoto Technopolis lies on Kyushu, the

southernmost of the country's four main islands, far from the congestion of the Tokyo-Osaka corridor.

In South Korea, Daedok Science Town is almost 160 km south of Seoul, the capital that in many ways dominates the nation. When completed next year, the complex will contain 55 research institutes and a population of about 50 000.

Among its tenants are Korea's Advanced Institute of Science and Technology, Naval Technology Institute, Energy Resources Institute, Electronics and Telecommunications Research Institute, Aerospace Science Institute, and Science Foundation.

Preferential tax incentives and other such lures help to entice larger companies to science parks and regions. Companies coming into Taiwan's Hsinchu, for example, receive the same sort of tax breaks as the Taiwanese Export Processing Zones. The Government can also reduce land rents to zero for five years for businesses that it deems highly desirable.

Tenants' proximity to ITRI, with its 5000-

Science parks in the power crescent

Institution	Place	Description
Japan		
Tsukuba Science City	60 km northeast of Tokyo	285.6 km ² . Contains 9 research laboratories and institutes administered by the Agency of Industrial Science and Technology, the University of Tsukuba, and private research institutes operated by NTT, Kobe Steel, and Sanyo among other companies. The city's population (4/1990) is 166 000 with 102 000 researchers and 5000 research staff. Planned population is 220 000. Tsukuba Center (18 320 m ²) is associated with 70 companies; total investment, 4.7 billion yen
21st Century Plaza	Sendai City, Miyagi prefecture	8502 m ² . Operates in collaboration with the University of Tohoku and 70 companies. Investment: 4.8 billion yen
Eniwa Business Research Park	Eniwa City, Hokkaido	9800 m ² . Associated with the University of Hokkaido and 37 companies. Investment: 2.5 billion yen
Nagaoka Research Park	Nagaoka City, Niigata prefecture	46 996 m ² . Associated with the Technical University of Nagaoka and 9 companies. Investment: 3.81 billion yen
Toyama Center	Takaoka City, Toyama prefecture	38 467 m ² . Associated with the University of Toyama and 10 companies. Investment: 3.3 billion yen
Kanagawa Science Park	Kawasaki City, near Tokyo	17 513 m ² . Associated with various institutes in the Tokyo area and 127 companies. Investment: 18.4 billion yen
Kurume Techno Research Park	Kurume City, Kyushu	12 527 m ² . Associated with the universities of Kurume and Kyushu and 30 companies. Investment: 2.7 billion yen.
South Korea		
Daedok Science Town	Taejon City	28 km ² . Includes 13 government institutes (such as the Korea Institute of Science and Technology), three private institutes (such as the Lucky Central Research Institute), and three universities and professional schools. Goal is to locate 55 institutes with staff of 50 000 by 1992
Taiwan		
Hsinchu Science-Based Industrial Park	Hsinchu	4 km ² . Includes about 120 companies in high-tech industries such as integrated circuits and optoelectronics. Associated with the Government's Industrial Technology Research Institute and two major universities located nearby
Singapore		
Singapore Science Park	Singapore	101 600 m ² . Includes (1988) five Government organizations (like the Singapore Institute of Standards and Industrial Research and the National Computer Board) and 45 private companies. Two universities and a polytechnic are either nearby or tied in

Sources: Tsukuba Science City Public Relations, KIST, ITRI, Singapore's EDB

member staff and its status as the center of Taiwan's R&D activities, also is ■ lure. ITRI's involvement in the development of IBM-compatible computers illustrates why. After it brought some 20 firms together to begin the effort in 1985, others climbed aboard—Tatung Co. and Datatech Enterprises Co. among them. In 1989 ITRI's Computers and Communications Laboratories signed an agreement with California's Sun Microsystems Inc. to license Sun's Sparc chip for the program. Prototype workstations were demonstrated that year, and the first commercial model was introduced by Tatung in late 1990, a mere five years after ITRI's orchestration began.

On mainland China, just one hour by hoverferry from Hong Kong, the Shenzhen Special Economic Zone's Science and Industry Park encourages foreign investment in much the same way—with preferential tax rates, rents as low as one-eighth of those in Hong Kong, and cheap labor, water, and electricity. The result: of the 42 companies in the park, 18 are involved in joint ventures with overseas firms.

Once a few foreign operations establish themselves in science parks and comparable institutions, others often follow. Three years ago, for example, Texas Instruments Inc. began hiring Indian engineers in Bangalore to develop software there for use in the United States—at about one-sixth the U.S. cost. Impressed by its success, Hewlett-Packard Co. and the Australia and New Zealand Bank Group Ltd. started similar ventures.

Hsinchu's Science-Based Industrial Park has gone further than most in reaching out overseas. As part of the Taiwan Government's effort to bootstrap itself up into the major leagues of high technology, park authorities have set out to coax overseas Chinese, especially those trained in the United States, into taking jobs in the park. Its red tile roofs and entryway mimic those of Stanford University, whose graduates immediately feel at home there. Alumni of other institutions are wooed with such perquisites as a bilingual school (for children whose early education has been in English), houses and apartments on site, along with banks, restaurants, supermarkets, and private clubs, and the opportunity to move rapidly up the promotion ladder.

The park is thought to have been largely accountable for the return home in recent years of hundreds of native-born Taiwanese, U.S.-trained engineers. One was the entrepreneur Matthew F.C. Miau, chairman of Mitac Computers Group, who left a job designing microprocessors at Intel Corp. in California.

CONDITIONS OF ENTRY. In several cases, companies must fulfill specific criteria before they are granted places in ■ science park. To gain entry to Korea's Daedok Science Town, for example, firms must buy 1000 pyong of land on the site (1 pyong = 3.3 m²)

at the going rate of 300 000 won (US \$413) per pyong. Companies applying for admission to the Singapore Science Park must satisfy ■ committee on five counts. They must have a substantial R&D budget in relation to their total operating budget; offer products or services of a high technological standard and with high value-added per worker; and have ■ high percentage of their workforces in technical and R&D work. Also, their operations must have a catalytic effect on the growth of the park, and their work be nonpolluting or land intensive.

Hsinchu has similar criteria for the percentage of revenues to be spent on R&D and the proportion of scientists and engineers in the labor forces. Even China's Shenzhen Science and Industry Park is prepared to close down companies whose products, in the park board's opinion, are not of high enough quality to sell overseas. In 1989, for example, the park shut down a two-year-old company that its board believed was producing goods not high enough in quality to offer overseas. Shenzhen also demands low pollution. **DIFFERENT DRUMMERS.** Several science parks have specific themes. These may reflect the broad interests of the local populace or else give governments and local authorities the opportunity to build up healthy export businesses by concentrating specialist organizations in one neighborhood. In Iizuka, another town on Japan's island of Kyushu, for example, the local technopolis has become the site of a new Fuzzy Logic

Taiwan's science park helped lure home hundreds of native-born, U.S.-trained scientists and engineers

Systems Institute. In the minds of Japanese consumers, fuzzy logic has become almost a cliche for high-tech inventiveness; companies extol its virtues in such appliances as washing machines and vacuum cleaners.

On the same island, Kumamoto supports ■ large agricultural center that contains 70 greenhouses and carries out research in biotechnology for cattle and plant breeding. But it has also built up an awesome capacity in ICs, and has plans to become a major Asian hub of information.

Singapore's Science Park has become the focus of ■ budding biomedical industry, producing everything from AIDS diagnostic kits to prosthetic heart valves. And Hsinchu boasts four world-class plants for manufacturing computer chips. In fact, Hsinchu, having almost run out of space, is leapfrogging to a 2.5-km² site farther out in the countryside.

Hsinchu's administrators have long wanted to expand, but local residents resisted

surrendering the necessary land. Instead of the 3.2 km² originally envisioned for expansion, park administrators then settled for 2 km². But the delay may have proved fortunate; it led to a revised scheme to expand on cheaper land some distance from the park, creating a tripolar zone modeled after Research Triangle Park in Raleigh, N.C., and Tsukuba Science City.

According to Steve Heieh, director general at Hsinchu, Taiwan's Science City will encompass ■ huge complex of roads, housing, and other infrastructure development that may take 10 years to complete. One core feature will be a supercomputing center with an optical-fiber telecommunications network linking the entire triangle.

"Hong Kong is a financial center," he told a reporter. "We will be an R&D center." **DOWNS AND UPS.** Like true love, the course of science park development scarcely can be said to run smoothly. In Guangdong, for example, the Shenzhen park has faced potential electric-power shortfalls. Despite the prospect of 275 MW more from two fossil-fuel power plants going on stream soon, its managers do not expect to breathe easily until a Daya Bay nuclear plant begins operation in 1992.

Nonetheless, as if to prove the science park is an idea whose time has come, MITI in Japan has elected to carry the notion a step further, with a grand plan for some 40 semi-rural technopolis centers for engineers and computer scientists. The Iizuka technopolis on the island of Kyushu is one example.

A former coal-mining town whose population had fallen from 120 000 to 60 000, it has with MITI's help replaced unsightly coal-slag pyramids with parks, shopping districts, and new institutions such as the Kyushu Institute of Technology (KIT). KIT, whose faculty includes 200 computer scientists, is involved in such fields as artificial intelligence and control engineering and science. This effort is intended to be ■ base for research in advanced manufacturing processes, including testing automated production techniques on working assembly lines. Matsushita Electric Industrial Co. is only one of several companies with plans to establish R&D centers in the area.

LATECOMERS. The obvious success of such centers of excellence, combined with a feeling that the Government must actively help get new technology off the ground, has persuaded the one recalcitrant tiger, Hong Kong, to start its own small edifices. Work on a HK \$200 million (US \$26 million) technology center near Hong Kong's City Polytechnic will start later this year and is to be completed in 1993. Closer at hand, a committee headed by Motorola Inc.'s Asia-based vice president C.D. Tam has recommended that the territory's Government start a Science Park near the new University of Science and Technology, which will open in October.

The most ambitious project in the region is Shanghai's plan for Pudong. Quarter-backed by the city's charismatic mayor Zhu Rongji, recently promoted to one of China's five vice premierships, the plan envisions two export processing zones, a science park, a financial zone, and a second international airport in a rundown area across the Huangpu River from Shanghai itself. Observers have doubted Zhu's ability to obtain the foreign financing needed for the development, given China's faltering economy and memories of the Tiananmen Square massacre of 1989.

But as reformist Zhu ascends the ladder of power, those doubts may dwindle. If it is built, Pudong could become one of Asia's larger centers for emerging technology. ♦

EDUCATION & TRAINING: grueling conditioning for lifetime learning

George Watson Senior Editor,
Karen Fitzgerald Associate Editor

Through schools from northern China to southern Malaysia run common threads of veneration for knowledge, devotion to family and country, and respect for social cohesion—all legacies of Confucius. Education, including technical studies, is taken very seriously in the countries of the region, reflecting that shared heritage.

East Asian students are subjected to a regimented though supportive environment. They are expected to work hard and learn well—and they do. Though educational differences do exist among the countries, they are caused by varying economic goals and local political philosophies.

Science education in Japan starts early. Through such events as science fairs, young people are encouraged to aim for the science and technology professions, which are viewed with great respect. By national edict, elementary school students devote 25 percent of their class time to mathematics and science. Their schedules in both primary (elementary) and secondary (high school) classes are intensive, with a long school day, at least 2 hours of homework every night, a 5 1/2-day week, and only brief vacations. (Schools are open 210–240 days a year compared to 180 days in the United States.)

Yet even this grueling schedule is not enough for many Japanese parents eager to have their children admitted to the "best" universities. At considerable expense, they send their offspring to private cram schools—*juku*—to supplement their public school learning. Some 71 percent of elementary and junior high school students attend *juku*, and the figure rises to 80 percent for those in senior high school. Parents spend about 5 percent of their annual income on cram courses, according to a 1989 survey by the Tokyo Metropolitan Government, mak-

ing *juku* a billion-dollar industry.

Such monetary sacrifices by parents—as well as leisure time given up by students—are required because of the country's rigid system of university entrance examinations. A uniform entrance exam—the Joint Achievement Test—is administered nationwide, and only students with high scores can hope to be accepted at the elite universities—from which lifetime employment by top companies is virtually guaranteed. Among the coveted schools are Tokyo University (the most prestigious), Kyoto University, and the Tokyo Institute of Technology, all public, and the private institutions Waseda University and Keio University.

In Japan, a high-school graduate has acquired the same mathematics and scientific knowledge as a college sophomore in the United States. The country's illiteracy is less than 1 percent of the population compared with 13 percent in the United States and 3 percent in Europe, including the Soviet Union. Internationally Japanese youth consistently score first in annual mathematics tests.

Planning, organizing, and managing the primary and secondary schools for the entire country is handled by the Ministry of Education, Science, and Culture (Monbusho) in Tokyo. In the United States, in contrast, more than 15 000 independent school districts perform the same functions.

Monbusho requires teachers nationwide to follow a set curriculum and use only official textbooks. This centralized control caters to neither the very bright student nor the underachiever.

"There are no special programs—the system aims to produce students who are all at about the same level, and it is generally successful at this," Jill Miller, a Tokyo-based former teacher in Japanese schools, told *IEEE Spectrum*. "This is achieved at great cost—the pressure to keep up means Japanese high school students are forced to study for very long hours compared to their western counterparts. I saw what a toll it took on my own high school students. It is not much of a life!"

One of the notable changes in Japan in the postwar period was in the system of higher education. Under the old system, there were several levels of institutions of higher learning. After World War II, these were integrated into a single level of universities that incorporated portions of the U.S. style of curriculum.

At the college level, Monbusho completely finances and sets policy for about 100 national universities. Also part of the university system are about 30 additional public institutions established by local governments and more than 300 private institutions.

Surprisingly, once in engineering school, students can relax a little. With their solid grounding in math and science and their ingrained discipline and dedication, many can almost breeze through the courses. They rarely flunk out. The pace steps up some-

what in the junior and senior years, when students carry a heavier load of engineering classes and laboratory work.

TRAINING ON THE JOB. Engineering students do not specialize. Their prospective employers prefer it that way. "In Japan industry is a part of the overall education process," Lawrence P. Grayson, who organized a major bilateral study by Japan's Monbusho and the U.S. Department of Education, told *Spectrum*. "Large companies provide continuing education in company schools and on-the-job training as a matter of policy. Japan's lifetime employment system makes it economically sound for a company to train young employees. An employer has little fear that a young engineer's newly acquired expertise will be lost to a competitor."

Justin Bloom, a former counselor for science and technology affairs at the U.S. Embassy in Tokyo, told us: "When B.S. engineers [in Japan] enter industrial employment, they often work on the shop floor initially and are moved from job to job—including nontechnical assignments such as accounting and marketing—until those who reach management have worked in every part of the company. I don't see how

The engineering profession in Japan and the four tigers

Country	Engineers in workforce (year)	Engineering graduates (year)
Japan	1 124 300 (1985)	77 009 (1989)
South Korea	17 575 (1985)	28 071 (1990)
Taiwan	179 495 (1990)	7 994 (1988)
Singapore	10 000 est. (1991)	1 347 (1991)
Hong Kong	42 000 (1990)	3 096 (1989–90)

1 B.S. or equivalent.

Source: Center for International Research, U.S. Bureau of the Census; NSF (Division of Science Resources Studies) Taiwan government sources; National University of Singapore; Department of Electrical Engineering; and University and Polytechnic Grants Committee of Hong Kong

this could happen unless their education was broad." Bloom is now president of Technology International Inc., a Potomac, Md., company specializing in U.S.-Japan technology transfer.

Japan graduates over 77 000 engineers per year. About 11 000 M.S. engineering degrees are awarded annually, and roughly 1500 Ph.D.s, including conventional course doctorates (*kosu hakushi*) and the more numerous doctorates based only on a dissertation on industrial research (*ronbun hakushi*). In comparison, the United States graduates about the same number of engineers with a B.S., 30 000 with an M.S., and 3800 with a Ph.D. equivalent to *kosu hakushi*. (Half the doctorates in the United States go to foreign nationals.) The European Community graduates approximately 100 000 engineers annually.

"Private industry in Japan is not impressed with the quality of postgraduate education in the universities and prefers to hire B.S. or M.S. graduates and then provide further training in company-run institutes or by sending employees to other countries for further academic or research experience," Bloom said.

Many in Japan believe that industry's emphasis on in-house training is short-sighted. Hiroshi Inose, director of Japan's National Center for Science Information Systems, believes that reliance on corporate instruction produces a narrow perspective, and that industry should contribute financially to upgrade Japan's understaffed universities and poor research facilities.

Writing in the Tokyo newspaper *Sankei Shimbun*, Inose said, "Many Americans praise Japan's educational system but few realize that the excellence ends with high school. Japanese colleges and universities are so inadequate that big business relies on in-house training to get topnotch engineers and computer programmers or sends promising employees to graduate schools in the United States. Higher education's shortcomings hobble Japan's move to the forefront in frontier industries."

MORE JOBS THAN JOB-SEEKERS. The founders of Japan's postwar educational system recognized the need for engineering technicians and technologists. They instituted five-year technical colleges combining vocational high schools with two years of college, including college-level courses in engineering and science. Graduates find ample job opportunities and the same kind of continuing education in industry as engineering graduates.

Indeed, the demand for all technical and professional graduates exceeds the supply. The Ministry of Labor estimated last year that 2 million jobs are unfilled, with the worst shortages in small and medium-sized companies. This is a result, not of a lapse on the part of Monbusho, which has always striven to provide the kinds of workers Japanese businesses need, but of the facts of contemporary Japanese life: a superheated economy, restricted immigration, and a declining birth rate and aging population. Moreover, many job-seekers are accepting positions in business and finance because these fields offer higher salaries than technical jobs.

This shortage of technically trained labor has benefited Japanese women, once confined to clerical jobs. "Companies now hire women graduates from departments of literature and train them in science and engineering," Toshiaki Ikoma of the Institute of Industrial Science at the University of Tokyo told *Spectrum*. "The Japanese system is very flexible compared to that of the United States, since Japanese companies educate employees and their prior qualifications are not so important."

The Japanese education system has been admirably successful in doing what its

founders set out to do in post-World War II years: produce the workers needed to implement a national economic strategy of adopting technology from other countries, improving it, and designing, manufacturing, and marketing products based on that technology. The graduates of the system are well-grounded, disciplined, dedicated, team-minded, and ambitious—just the qualities needed to transform basic dynamic RAM technology, for example, into what may be the highest-quality, least costly megachips in the world.

But in the fast-changing fields of ICs, software, computers, and telecommunications equipment, innovators have the competitive advantage. "For the first time," Lawrence Grayson said, "Japan is faced with the need to advance knowledge, do ground-breaking research, and create its own technologies."

Many Japanese educators are well aware of the challenge. "Educational institutions have managed to supply the large number of personnel needed to support the period of economic growth and quick industrial buildup," Hiroshi Inose told *Spectrum*. "However, it is also true that higher education has become extremely uniform, and the establishment of a large number of universities has reduced the funds and human resources available to each, leading to the deterioration of basic research at universities. Reconstruction of centers of excellence among Japanese universities is ur-

gently called for. Such centers are absolutely necessary to foster human resources capable of conducting creative basic research."

Fostering creativity will not be easy. The education system remains rigid. Many western educators believe that the individualism and heterodoxy that go with creativity may be diametrically opposed to Japanese culture. Yet, as Grayson has noted, the innate creativity of children is not lacking.

"I watched 10 gradeschoolers in a Tokyo classroom solve the same algebra problem," he said. "I saw 10 different solution methods—each correct. There's no lack of originality there."

YANGBAN MENTALITY. Education is accorded perhaps even more reverence in South Korea than in Japan. The heritage of *yangban*, the highly respected scholar class that dominated Korea's early history, still permeates the education system.

Indeed, education is considered so important that parents endure the harshest sacrifices to make sure their children have a chance at the top universities. Students' 12 years of preparation culminate in an 8-hour examination that determines whether they will be accepted in the top universities—Seoul, Yonsei, Koryo, Hanyang, and Pohang—and find a guaranteed place among the South Korean elite. Those who fail or only find a place in the "also-ran" universities are faced with greatly reduced job prospects. So intense is the pressure that every year several students kill themselves before the test and several more take their own lives after failing it.

Despite continual protests from educators, parents, and students that *hangyok gosa*—the rigid exam system—puts unnecessary pressure on students and is unsuited to the needs of the South Korean economy, the country's education authorities have done little to reform things. One reason is the sweeping political changes of the last four years, during which time major cabinet switches have occurred, including the ministers responsible for economic planning, industry and trade, science and technology, and education.

In this volatile environment, the Government has been unable to develop a coherent policy for educational reform to support economic growth. Technical education has suffered accordingly; there is an acute shortage of engineers, technicians, and scientists at all levels.

South Korea, with a population of 43 million, graduated about 28 000 engineers last year with B.S. degrees, 3900 with an M.S., and 450 with Ph.D.s. The B.S. engineering curriculum resembles that in the United States: two years of basic science and two years of engineering specialization. "The U.S. engineering schools have much better lab and computer facilities and better student-to-faculty ratio," said Imsong Lee, who received his baccalaureate engineering degree in Korea and is now president of Kasic Systems Inc. in California. "The Asian curriculum tends to be more analysis and textbook oriented while the U.S. curriculum has a more innovative orientation toward engineering theory and design, laboratory projects, and hands-on computation."

Korean students are attracted to technical careers by offers of special scholarships, exemption from military service, and the prospect of rewarding employment after graduation. Regional technical high schools throughout the country offer academic and financial incentives to recruit talented students. From high school, many of them enter the Korea Advanced Institute of Science and Technology (KAIST), which maintains an undergraduate institution exclusively for recipients of prestigious national science scholarships.

KAIST also offers master's and Ph.D. degrees, as do such major institutions as Seoul National and Yonsei universities. However, many B.S. graduates eventually go to U.S. universities for advanced degrees at their employers' expense.

Despite the incentives, the Korean edu-

Elementary schools in Japan devote 25 percent of their time to math and science

cation system cannot keep up with industry's demand for engineers, programmers, and scientists. Hyong Kap Kim of the University of Manitoba's Electrical and Computer Engineering Department spent his sabbatical last year at Seoul National University. "Ten big firms, including Samsung, Hyundai, Goldstar, and Daewoo, needed 6500 electrical and electronics engineers this year," he told *Spectrum*, "but secured only 3900. The ratio of supply to demand averages out to 0.6 over all engineering fields."

"In industry's view, educational policy is woefully inadequate in providing the technical workers needed by industry," Imsong Lee said. "The shortage is affecting the performance of individual companies and the whole economy. Neither Government policymakers nor industrialists realized the magnitude of investment and long lead time necessary for building the educational infrastructure to support sustained growth over the long term."

Moreover, Korea is no longer a low-wage country. All of a sudden, Korea must develop high-value-added products at home and produce them in other Southeast Asian countries where the labor cost is still low. As in Japan, creative engineering is needed. Also like Japan's, Korea's education system fosters conformist attitudes and group cohesion. "Nonconformists are treated as social misfits and penalized," Lee said. "Creativity and innovation, however, require unconventional imagination and nonconformist ideas."

John Shaw, president of the Korean branch of the chemicals giant Imperial Chemical Industries PLC, believes his greatest problem is getting new employees, even those from the best universities, to solve problems in a rational way. "The education system concentrates on cramming in knowledge, but not on problem-solving," he told *Spectrum*.

The English-language *Korea Daily* summed up frustrations bluntly in an editorial last December: "The present system has it everything the educators say is bad. It promotes mechanical, rote memorisation and cramming, which leaves little room for thinking, reasoning, or otherwise free exercise of the mind. Everything is geared to that supreme event called the college entrance exam."

Signs of change are evident, however. Early this year, the Ministry of Education announced that, beginning in 1994, at least 40 percent of a student's evaluation should be based on a report and recommendation from the applicant's high school, and the rest of the filtering process should be left to the universities to administer individually. "The new approach could imply a significant departure from the age-old rigid uniformity toward some measure of diversity," Hyong Kap Kim observed.

At the same time, the Government is seriously contemplating enlarging its engineering schools. The Department of Commerce and Industry has launched a study of the



Students in Taiwan line up to try personal computers at a fair. The Institute for Information Industry sponsors hands-on demonstrations to stimulate interest in computer science.

feasibility of doubling enrollment at Seoul National University's engineering college, Kim said.

NO TRAILBLAZING. The Taiwanese Government deserves much of the credit for the island's economic growth, and the Ministry of Education's emphasis on science and engineering is part of that story. Taiwan's engineering schools graduated an estimated 9000 people with degrees in 1990. Another 5000 received degrees in computer science and mathematics—twice as many as eight years ago. Altogether, about 40 percent of the degrees awarded last year were in technical subjects.

In its industrial development policy, the Government is not looking to blaze new paths in technology. Its strategy is to cash in on the large follow-up market for already established products such as hard-disk drives, printers, and, now, portable computers. Curricula in the engineering schools reflect this policy, and students are given a solid background in math, science, and basic engineering. Those going on to graduate schools may also benefit from the National Science Council of the Republic of China, which supports graduate research.

Taiwan's most prestigious electrical and computer engineering departments are in National Taiwan University, Taipei, and National Tsing Hua University and National Chiao Tung University, both in Hsinchu. In fact, Hsinchu, with two universities, the Industrial Technology Research Institute (ITRI, Taiwan's version of Japan's MITI's AIST), and the Hsinchu Science-Based Industrial Park, is a major breeding ground for top engineers. Currently Hsinchu's students and faculty number about 8000.

One of Taiwan's few large companies, Tatung Corp., has even set up its own university—Tatung Institute of Technology,

Taipei—as a source of engineers and managers as well as for technology advances.

Despite the high quality of Taiwan's education system, many parents hope to send their children abroad for study—and many of them do, especially to the United States. Study abroad has a historic precedent. The Kuomintang party, as rulers of mainland China, used technocrats trained abroad, and brought with it its tradition of seeking foreign training when it relocated to Taiwan after the ascendancy of the People's Republic in 1949.

Many of those who study overseas do not return to Taiwan. A large portion of Asian engineers in California's Silicon Valley are Chinese from Taiwan. Lately, however, a reverse trend has been noted: Chinese are returning to Taiwan to set up their own companies. The Taiwanese have a tongue-in-cheek acronym for those who do: CEOs, or "Chinese entrepreneurs from overseas."

SPECTER OF '97. Hong Kong has 40 000 students attending institutions of higher learning full-time. The British crown colony, with a population of 5.9 million, will graduate 3000 engineering students this year, largely from the University of Hong Kong, the Chinese University of Hong Kong, City Polytechnic of Hong Kong, and Hong Kong Polytechnic. All receive government support.

Ten years ago, graduates tended to stay in the territory, but today much of the cream goes abroad—to the United States, Canada, Australia, and Great Britain. The trend appears to have accelerated after the 1989 Tiananmen Square uprising in Beijing. The Government projects a net outflow of 425 000 for 1989–96, of whom 78 000 will have at least some college-level education. The Sino-British Joint Declaration that the prosperity and stability of the territory will

be maintained, and the promise by Chinese leaders to preserve Hong Kong's economic system and entrepreneurial spirit after the transfer of power to China six years from now, have done little to dispel a general lack of confidence, particularly among intellectuals and professionals.

Meanwhile, Hong Kong's Government is being urged continually by leaders of industry and academia to abandon its laissez-faire policies and play an active role so that the territory can compete with fellow Asian tigers in the future [“How government helps: MITI and its clones,” p. 53]. Among other actions, the Government is building and staffing a new campus, the Hong Kong University of Science and Technology, scheduled to open in October, which is expected to graduate more than 250 engineers yearly by 1994.

TRICKLE OF ENGINEERS. Though engineering schools are improving in the Southeast Asian nations of Singapore, Malaysia, Thailand, Indonesia, and the Philippines, these countries are competing for a mere trickle of graduating engineers. To lure graduates away from higher-paying jobs in Singapore, Malaysia increased its engineering salaries by 20 percent last year, but bucking a similar dearth there, Singapore was forced to boost wages an additional 25 percent, according to the Jan. 14 issue of *Electronic World News*.

Singapore, with an estimated 10 000 engineers, is better placed than the other four. Smaller and more developed, its electronics industry is fairly well-established. Its two engineering schools, at the National University of Singapore and Nanyang Technological Institute, are drawing engineering students from nearby countries, some of whom would otherwise have left the region to study in North America, Great Britain, and Australia.

Even so, Singapore companies so hurt for engineers that they send recruiters to foreign universities that graduate Singaporeans. To strengthen education within the country, Singapore's Ministry of Trade and Industry has targeted engineering and information technology as two of three postgraduate areas that need expansion—part of a multimillion-dollar plan to upgrade infrastructure and raise academic standards. Last year the Nanyang Technological Institute established ties with the United States' Massachusetts Institute of Technology Sloan School of Business and will become a full university this summer.

The other, still-developing countries are hungry for engineers to carry on their industrialization. Indonesia, for example, graduates less than 7000 engineers each year, but needs an estimated 25 000, according to Giri Kartono, the Indonesian embassy's education attache to the United States. Most graduates are civil and mechanical engineers, even though demand is higher for electrical and electronics engineers. To redress the shortage, the engineering schools

at seven of Indonesia's state-run universities began offering crash programs in 1985. The Government has also been sending the universities' teachers abroad to get doctorates and upgrading books and laboratory equipment to raise the quality of the school's programs.

Additional schools in the region gaining better reputations are Chulalongkorn University in Bangkok, the University of the Philippines in Manila, the University of Science in Penang, Malaysia, and the University of Malaya in Kuala Lumpur.

In Thailand, engineering is second only to medicine in academic difficulty and career prestige. In the past, most students taking engineering were children of civil servants who wanted their own lifetime careers as civil engineers with the Government, according to Srinol Povatong, deputy permanent delegate for the permanent delegation from Thailand to the United Nations Educational, Scientific, and Cultural Organization. But demand for engineers from the private sector has surged because of rapid industrial expansion, Povatong said, and engineering

Japanese grade schools are open up to 240 days a year, compared to 180 days in the United States

students now are more often from the families of businessmen and industrialists and tend to take electronic and computer engineering.

In contrast to other Asian nations, there is a glut of engineers in the Philippines as a result of the high unemployment brought about by the Government's recent upheaval. Many Filipino engineers go abroad, usually to the Middle East, to find employment, according to Amador Alumia, a telecommunications engineer with AT&T Philippines.

Electronics engineers are in shorter supply than others because the Government created a license for electronics and communications engineers only in the early '70s, and many engineering schools, even the state-run University of Philippines, do not yet offer the curriculum. Alumia received his degree from the University of Santo Tomás, run by the Roman Catholic church. The tuition at the state and church-run universities in the Philippines is so low that these schools draw many foreign students.

To keep current, Filipino engineers go abroad to take courses at the expense of their companies; Alumia, for instance, recently went to the United States to take a two-week course on a communications technology called VSAT (very small-aperture terminals), given by the United States Telecommunications Training Institute, a

nonprofit organization in Washington, D.C.

Weak economic conditions in Malaysia have lessened demand for civil and mechanical engineers there, but not for electrical and electronics engineers, who are needed by local U.S. semiconductor manufacturing operations, including Motorola, Intel, and Texas Instruments.

According to Shamsudin H.M. Amin, head of the control engineering department at the University of Technology in Malaysia, many students sign up for medicine and engineering because those are the only professions that pay enough to let them buy a house and car. Places are limited at the country's engineering schools, so many must study in countries like the United Kingdom, the United States, and Australia—at far higher tuitions. Shamsudin estimated that 20 000 Malaysians are now attending U.S. schools alone.

One shining center of technical education in Asia is India, and in particular, Bangalore in the state of Karnataka. In Karnataka alone, there are 43 engineering colleges turning out 11 000 engineers each year. Many foreign high-tech companies have begun to locate there to take advantage of the cheap labor for computer programming and engineering. Texas Instruments Inc. established a software research center in Bangalore for computer-aided design of semiconductor chips. The city also has a major center for basic science research, the Indian Institute of Science, that was modeled on the California Institute of Technology by Nobelist and physicist Chandrasekhara Venkata Raman.

Bangalore's high-tech focus is due to its roots as a British army post, which attracted defense industries. India's National Aeronautic Laboratory, the Indian Space Research Institute, and the Electronic and Radar Development Establishment are located there.

THAILAND TOO. The Asian Institute of Technology in Bangkok is also a rich source of engineering expertise for the region. Financed with aid from Australia, Thailand, Germany, Japan, and other countries, the school has an international faculty and offers only masters and Ph.D.s in engineering and related fields. Most students attend on scholarship and more than 95 percent settle in the region after graduation. The institute has been so successful that some contributors, including the United States and Australia, have been cutting back aid. The school hopes to solicit more funds from private industry and foundations to make up for the decline.

For 20 years, a plan has been floated for a University of Southeast Asia, which would have rigorous standards on a par with Harvard and Oxford universities. The fundamental issues of siting and financing have yet to be settled, though financing by the governments of the Association of Southeast Asian Nations has been proposed. ♦

Asiapower 2000: what's next

Government officials, academics, and industry leaders in Asia point to priorities for the growth of technology in their countries

S

ignificant advancements in optoelectronics and information technology are likely to be made by several East Asian countries in the next decade. Others will concentrate on upgrading manufacturing capability and product design. For many, telecommunications technology will also play a central role, as will energy conservation and finding alternative energy sources for petroleum. And for some Asian countries, simply feeding and clothing their people will be the focus. But even here, technology will likely afford an important contribution.

JAPAN: avoiding cartels in any form

In Japan, new systems and services are increasingly dependent upon technological innovation in devices and materials, on the one hand, and in software, on the other. What will have an enormous impact on the economy in the long run will be devices and materials technologies, including optoelectronics and bioelectronic technologies as well as those in knowledge-based software.

In addition, highly intelligent production technologies, human friendly interfaces, and supercomputer-oriented cultural technologies (interactive art, virtual realities, and the like) may undergo revolutionary development.

But to achieve this impact, education, particularly graduate education, must be drastically strengthened so that a sufficient number of talented scientists and engineers are trained in the critical areas of optoelectronics, bioelectronics, and software science. A move toward this end was the establishment of the Research Center for Advanced Science and Technology at the University

of Tokyo in 1987. Although this center is still small, its international, interdisciplinary, and open-ended approaches have been well accepted by the Government and researchers.

While graduate science education is currently less than adequate, science has been taught satisfactorily in primary and secondary schools. As a result, the working population in general is technologically literate.

Future technological breakthroughs will also require that researchers in the social sciences and the humanities as well as in engineering and the sciences are included in any interdisciplinary collaborative ventures.

Researchers also need better working environments, so investments in industrial basic research laboratories will be expanded. Funding for automation is also increasing significantly to cope with the shortage of manpower.

Japan welcomes technological competition with other countries because competition brings benefits not only to the users but to the competing entities. And when the world economy continues to grow, the major technological powers play a positive-sum game, rather than a zero-sum game. For this reason any form of national or international cartel should be carefully avoided.

One potential obstacle to future development is environmental problems. Among them, radioactive pollution from the accidents of nuclear plants should be considered very seriously since both developed countries and developing countries are becoming increasingly dependent on nuclear ener-

gy. The major technological powers should collaborate on safe and inexpensive nuclear plants and should share that technology with developing countries without any restriction.

For the developed countries, cross-licensing and other arrangements between private industries will continue to play a major role in technology transfer. By contrast, universities and national laboratories may play only a limited role in this respect because most of their attention is centered on new discoveries and their achievements are openly published.

—*Hiroshi Inose, director general, National Center for Science Information Systems, Tokyo*

SOUTH KOREA: securing brainpower for research

To achieve international competitiveness, South Korea has set up five technical priorities: information technology, robotics, new materials, chemicals, and biotechnology. In addition, technologies for energy conservation and substitutes for petrochemicals will play important roles because of the nation's increased energy consumption despite a foreseeable oil shortage.

One problem the country currently faces is that it has recently come to be treated as a competitor of the developed countries. Consequently, South Korea suffers from new pressures concerning protection of intellectual property rights, technology transfer restrictions, and increased royalties.

Such obstacles can be overcome by strengthening cooperation with the developed world as well as by enhancing indigenous capability.

But to do this, it is necessary to expand R&D resources for high-technology development, both human and capital. That goal is causing concern because achieving a national consensus among decision-makers to make it happen is an obstacle.

To this end, the Korean Government plans to expand science and technology investment to 5 percent of the gross national product by the year 2001. Both financial and tax incentives will be provided to induce R&D investment by the private sector. Furthermore, the education policy will be renovated to train high-caliber science and technology manpower.

Since design and engineering is currently the weakest link in developing



National Center for Science Information Systems, Tokyo

Japanese precollege education yields technological literacy

Hiroshi Inose, Japan

Tekla S. Perry Senior Editor

South Korea's technology industries, it might be necessary to more actively foster efforts to improve the quantity and quality of engineering companies. The Government has already amended some policies: ■ tax credit system applies to private R&D investment; imported R&D equipment is now exempted from tariffs; venture capital funding is being offered; and the nation's procurement policy has been revised to attract the private sector to longer-term R&D efforts.

In order to rank with the technologically advanced countries in the next century, the country has to secure engineering brains to develop an indigenous capability for creative research. Its plans are now geared to finding and cultivating the scientific talents of youths, on the one hand, and to linking university advanced degree programs and industrial demands through joint research projects, on the other. Also, the Institute for Culture of Science will be established to increase the public awareness of science and technology.

—Oh Chai-Kon, senior research fellow and technology forecasting group leader, Institute of Science and Technology Policy, Korea Advanced Institute of Science and Technology, Seoul

TAIWAN: large strides in R&D

In Taiwan's new six-year National Construction Plan (1990–96), the Government has identified eight key technologies and 10 high-growth industries that will receive special R&D support. The key technologies are optoelectronics, computer software, application of materials, industrial automation, advanced sensors, energy conservation, resource development, and biotechnology. The industries that are expected to expand here are communications, information, consumer electronics, precision machinery and automation, advanced materials, semiconductors, specialty chemicals and pharmaceuticals, aerospace, health and medicine, and pollution control.

Particularly in the last decade, Taiwan progressed significantly in advanced technologies and industries based on those technologies. For instance, in computers, semiconductors, consumer electronics, and industrial automation, Taiwan now has a healthy base; and it has made a promising start in specialty chemicals, precision machinery, and advanced materials, among others.

Future progress will depend heavily on continuing the development of these technologies at ■ fast pace. To do this, several sources will be tapped. The first will be Taiwan's own R&D effort, which, measured in dollar expenditures, is expected to increase at an annual compounded rate of 25 percent per year in the next five years. Second, investments in Taiwan by developed nations



cated funds to stimulate R&D in industry under ■ program known as the Research and Development Assistance Scheme (RDAS). This was followed in the mid-'80s by further R&D funding in the public sector, which led to the creation of research institutes for information and systems science, molecular and cellular biology, microelectronics, and manufacturing. These fledgling institutes together with our two universities are now the focal points of Singapore's research effort.

Our gross expenditure in R&D in relation to the gross national product (GNP) is far short of the advanced countries and the Newly Industrialized Economies (NIEs). The Government will continue to focus its major spending in the R&D area on infrastructure development, such as research centers and manpower training. It targets R&D spending to reach 2 percent of the GNP by the year 2000.

In January 1991, the Government established the National Science and Technology Board under the Ministry of Trade and Industry to promote R&D in the private and public sectors and spearhead the development of ■ better infrastructure for R&D manpower training and technology transfer. Within this decade, we should see the establishment of more research centers in Singapore and joint research centers in developed countries.

The most revolutionary developments from our R&D effort will occur in the now start-up areas of microelectronics and biotechnology. We are expecting breakthroughs in the design and fabrication of advanced semiconductor chips, and are optimistic that advances in tissue culture, hybridoma technology, and genetic engineering will give rise to exciting new industries here.

—Mah Bow Tan, Minister of State for Trade and Industry, Singapore

SINGAPORE: high hopes for ICs, biotechnology

For Singapore, the key to economic success is manufacturing. The health of Singapore's export-oriented economy depends heavily on our ability to sell our manufactured goods to the world market. To achieve this, we must not only constantly improve the quality of our products but also seek ways to reduce the cost of manufacturing them.

Therefore, the key technologies required to sustain the growth of Singapore's economy in the next decade and beyond include information technology, microelectronics, and automation. In addition, Singapore must develop its technological capability in such selected growth areas as new materials and biotechnology.

Our competitiveness depends on our ability to improve product design and productivity. We must also be able to react quickly to market changes and to take advantage of the often short life cycle of high-technology products. To accomplish these goals we must have the necessary skills and tools for design and ensure that automation helps us get the job done cost-effectively.

Obstacles in our country's path are the unavailability of R&D manpower and the lack of promotion of R&D in the private sector.

In 1981 the Singapore Government allo-

HONG KONG: seeking a surge of confidence

Looking into the future, by the year 2000, Hong Kong's prospects must be considered along with those of China. Hong Kong will continue to act as the "window to the world" for China, most importantly perhaps in the transfer of technologies.

The major technologies here will be fundamental ones, affecting the electrotechnical industries of the whole country. These include microelectronics and ICs, telecommunications, consumer electronics, and computer and information technology.

Of these, microelectronics is Hong Kong's weakest area, but it is key to a healthy electronics industry and must continue to be developed. China is still relying nearly totally on imported ICs.

The Government's general technology policy today is nonintervention, beyond

building up the infrastructure for manpower training. Recently, however, a change of mood has occurred and the Government is prepared to spend more money on this kind of development. So far, it has begun setting up a Research Council, making more money available for research, and building a Technology Center.

The biggest obstacle for Hong Kong's high-tech success is a lack of confidence. The development of technologies, especially the fundamental ones, require substantial investment and will not materialize into products and profits in a short time. At present, the uncertainty of the future of Hong Kong, despite the Sino-British Joint Declaration and the Basic Law, has deterred industry from investing.

Hong Kong currently has relatively free access to goods controlled by the Coordinating Committee on Multilateral Export Controls (Cocom) by virtue of its link with the United Kingdom and has developed an effective Cocom licensing and control system (similar to that of the UK). For technological advancements to continue, Hong Kong must have access to Cocom-controlled goods and techniques. Efforts are now being made to lobby authorities in the United States about Hong Kong's eligibility for the U.S. general license for intra-Cocom trade.

The brain drain problem is also a major concern for Hong Kong as most of the expected 400 000 emigrants are likely to be the best-educated professionals of the territory. To partially compensate, the Government has planned to increase university places by 100 percent by 1995, and it hopes to expand technical cooperation with China to tap manpower resources there.

The development of technology in Hong Kong requires a breakthrough in confidence so that both capital and manpower will continue to be invested here. Because of the problem of the transition of Government, it seems that very little technological transfer cooperation with the more developed countries is being considered. In the meantime, until the situation stabilizes and confidence is reestablished, the Hong Kong Government has to be more positive in formulating and implementing a solid technology policy like the rest of the tigers and Japan.

—Y.S. Cheung, senior lecturer, department of electrical and electronic engineering, and sub-dean of engineering, University of Hong Kong

CHINA: a vast, latent market for investment

Through the rest of the 1990s, China will continue to be a backward country. Since the greatest needs of the Chinese are to feed, clothe, and house their people, the technologies that will help most in providing these essentials will be those that influence agriculture, spur housing construction, and foster basic industries. For example, a very

important industry will be petrochemicals because they are the basics of fertilizers, plastics, and clothing fibers. For this reason, the Government will be more open to foreign investment in that sector.

Clearly more and more facilities to assemble basic electronic products for re-export will be built in China by companies from Japan, South Korea, Taiwan, and Hong Kong. But it will be more than 10 years before China begins developing its own electrotechnical infrastructure, with indigenous engineers doing the R&D.

The biggest obstacle to development of an electrotechnical industry is the Chinese Government because of its lack of understanding about international trade. How much China will grow technologically in the coming decade depends on the outcome of a political struggle to determine the succession of leadership in the Chinese Government. If the hard-liners win, China will remain technologically backward; if the middle-of-the-roaders win, China will have a chance to move forward.

There is a lot of investment money waiting at the borders. If the political environment improves, and if foreign investment can gain concessions from the Government (such as obtaining a means of exchanging Chinese currency for exportable money), investors from Japan, South Korea, Taiwan, Hong Kong, and other countries may be interested in moving in. Once the Chinese allow their currency to be freely exchangeable, a rush of investment would follow.

A looming concern is the most-favored nation trading status between the United States and China, which is currently up for renewal. A decision was to be made by President Bush by June 3. If this trading status is not renewed, the most outward-looking areas—the Guangdong province and the region around Shanghai—will be penalized and Government hard-liners will gain stature, choking technological development.

—David Brodets, senior consultant, Business International Asia/Pacific Ltd., Hong Kong

INDIA: a reservoir of trained specialists

Information technology, more than any other area of electrotechnology, will advance in India over the next decade and make major impacts on the country's economy. Among the industries that will grow are basic microelectronics, computer hardware, computer software, telecommunications (including electronic switching, satellite communications, and optical-fiber communication), and the handling of large databases—both geographically distributed and concentrated ones. Such technology can radically transform most sectors of the economy—including banking, insurance, industry, energy, and transportation—leading to much higher efficiencies.

Another area where information technol-

ogy will advance is in television and radio broadcasting across the country, which will have a major impact in conveying messages concerning education, health, sanitation, and the environment. Since India has most of its population in rural areas and a high percentage of illiteracy, visual images and voice communications are extremely important. Equally, non-voice data capabilities are critical for sectors that have to move forward rapidly, such as energy, transportation, industry, and finance. Therefore, the development of databases with a wide geographical spread and the ability to interconnect is clearly needed.

One set of obstacles to realizing the full impact of information technology relates to administrative practices, which tend to result in significant delays. The more important obstacle, however, is a lack of awareness and appreciation of how information technology can truly transform the economy.

While optical electronics is expected to grow strongly, presently research, development, and production in this area are insignificant. Striking advances will also be made in serial and parallel processing and connectivity as well as in database management and national information systems.

India is currently attempting to shift its technological development processes from a serial approach (a step-by-step innovation chain from R&D through production) to a more concurrent methodology, both to compress the time frame from start-up to production and to ensure that pricing and built-in quality in design, materials, and processing techniques lead to zero defects.

—M.G.K. Menon, former Minister of State for Science and Technology and Electronics, Delhi, India ◆

Acknowledgments

IEEE Spectrum called upon many experts in preparing this special report. We are especially indebted to the following consultants for their advice, although their identification with the report should not be construed as their endorsement of material included in it.

The advisory board was: Sougii J. M. Ann, professor, Seoul National University; Morarji V. Chauhan, president, Visram Motors, Madras; Y. S. Cheung, sub-dean of engineering, University of Hong Kong; Frank L. Huband, executive director, American Society for Engineering Education, Washington, D.C.; Toshiaki Ikoma, professor, University of Tokyo; V. Prasad Kodali, adviser, Department of Electronics, Government of India, New Delhi; Lin-Shan Lee, professor, National Taiwan University, Taipei; Ah-Choy Liew, professor, National University of Singapore; Hugo Rüchardt, senior director, Siemens AG, Munich; Michiyuki Uenohara, executive advisor, NEC Corp., Tokyo.

Invaluable field research was provided by Peter Gwynne, Hong Kong; Bruce Cheesman and Michael Breen, South Korea; Joyce P. H. Quek, Singapore; Chris Brown, Taiwan; and, in Japan, John Boyd, Robert Crawford, Stuart Dam-brot, Neil Davis, Simon Mansfield, Jill Miller, and Roger Schreifler.

We especially thank the following institutions for helpful information: Business International Corp., New York City and Hong Kong; Dataquest Inc., San Jose, Calif.; Elsevier Advanced Technology, Oxford, England; Motor Vehicle Manufacturers Association of the United States Inc., Detroit, Mich.

To probe further

EAST ASIA'S POWER CRESCENT

In *East Asia* (Houghton Mifflin, Boston, 1989), John K. Fairbank, Edwin O. Reischauer, and Albert M. Craig give the area's general historic, political, economic, and cultural background. James C. Morgan and J. Jeffrey Morgan provide insiders' views of Japan's economic organization in *Cracking the Japanese Market* (Free Press, New York, 1991). In *The Global Factory: Foreign Assembly in International Trade* (Brookings Institution, Washington, D.C., 1985), Joseph Grunwald and Kenneth Flamm examine the positive and negative aspects of producing labor-intensive goods in newly industrializing countries. *IEEE Spectrum*'s managing editor Alfred Balk analyzes the internationalization of economics and technology in *The Myth of American Eclipse: The New Global Age* (Transaction Publishers, New Brunswick, N.J., 1990).

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JTECH/Computer Science monitors Japanese technology for the National Science Foundation and other U.S. government agencies. Contact it at Loyola College, 4501 N. Charles St., Baltimore 21218; 301-323-1010, ext. 2876.

POISED FOR TECHNOLOGICAL LEADERSHIP

Consumer electronics—*JEI—Journal of the Electronics Industry*, an English-language monthly published in Tokyo, treats products, companies, and technology in the world consumer electronics industry.

ICs and computers—In *The Chip War: The Battle for the World of Tomorrow* (Charles Scribner's Sons, New York, 1989), Fred Warshofsky documents the competitive global status of the microelectronics industry. *Spectrum* describes cooperative R&D on microelectronics, computers, and software in Japan in "Electronics consortia to impact products for generations," October 1990, pp. 50-58. *Electronic World News*, a bimonthly published in Manhasset, N.Y., regularly reports on developments in Asia.

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ASIA'S COMPETITIVENESS FORMULA

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For more information about MITI's current efforts, contact the ministry at the Agency of Industrial Science and Technology, 3-1, Kasumigaseki 1-chome, Chiyoda-ku, Tokyo 100, Japan; (81+3) 501 1511. *News from MITI*, an English-language newsletter available only outside Japan, covers the organization's general activities. *The MITI Handbook* is a helpful English-language guide. Both publications can be obtained from MITI's Overseas Public Affairs Office at the address above; (81+3) 501 1331.

The Korea Institute of Science and Technology is at Box 131, Chongryang, Seoul, South Korea; (82+2) 962 8801. Taiwan's Industrial Technology Research Institute is at Building 11, 195 Chung Hsing Rd., Sec. 4, Chu-Tung, Hsinchu, Taiwan 31015; (886+35) 916 092. Singapore's Economic Development Board, Public Relations Division, is at 250 North Bridge Rd., No. 24-00, Raffles City Tower, Singapore 0617; (65) 336 2288.

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"Asia's Brain Wave," *Asiaweek*, June 29, 1990, pp. 30-39, is a continent-wide view of the boom in higher education. Included are brief descriptions of 34 of Asia's top educational institutions. ♦

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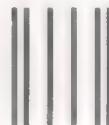
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This includes requirements development, conceptual design, formulation and execution of a technology plan. Eventually you will direct prototype development and evaluation, flight system development, contractor interfaces, testing, integration and operations planning. Requires an MS or PhD in EE, Physics, Applied Physics or Astronomy plus related experience. Background in control systems, opto-electronics and star data is desired.

Please submit resume to Department T-12.

Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive 249/104, Pasadena, CA 91109. Equal Opportunity Employer.



Jet Propulsion Laboratory
California Institute of Technology

Faculty Position The University of British Columbia Department of Mechanical Engineering

Applications are invited for a tenure-track position at the rank of assistant or associate professor in the Department of Mechanical Engineering. The appointee must have a Ph.D. degree, and be trained and actively involved in research in the general area of computer-aided-engineering with strong emphasis on design, preferably including computer modelling of components/materials, and the development and industrial application of computer aided design methods. Relevant industrial experience would be a significant asset. In addition to a continuation of active research in his/her area, the appointee is expected to develop and teach graduate and undergraduate courses in his/her field of expertise.

The appointment is supported by the UBC Centre for Integrated Computer Systems Research. The objective of this Centre is to foster interaction and collaboration among the academic researchers and their industrial colleagues in the areas of Computer Science, Electrical Engineering and Mechanical Engineering. The appointee will therefore be expected to become involved in interdisciplinary research with colleagues in these related areas.

Applications should be received no later than July 31, 1991. The appointment will commence September 1, 1991 or as soon as possible thereafter. Salary will be commensurate with qualifications and experience.

The University of British Columbia encourages qualified women and minority applicants. In accordance with Canadian immigration requirements priority will be given to Canadian citizens and permanent residents of Canada.

Dr. M. Salcudean, Head
Department of Mechanical Engineering
The University of British Columbia
2324 Main Mall, Vancouver, B.C. V6T 1W5
Canada

Associate Director CENTER FOR THE COMMERCIAL DEVELOPMENT OF SPACE POWER AND ADVANCED ELECTRONICS Space Power Institute Auburn University

The Center is seeking an individual to provide senior management and advanced technical support to the Director. Center programs include electric power distribution and management, advanced electronics and devices, thermal management, advanced concept sensors, power system components, development and characterization of new materials for space applications, space environment effects, neural networks, orbital debris, and space hardware development for testing and evaluation. Industries are joint participants in most research. The Center goals are to identify the technological impediments to specific space power needs, to characterize and conduct the enabling research, and to develop and qualify hardware for space based experiments.

Applicants should possess a strong technical background in engineering and/or sciences, having an earned doctorate and research leadership experience. Management experience is highly desirable. This position involves extensive interactions with academic and industrial researchers, as well as corporate management and government representatives. Excellent written and verbal English communication skills are required. Position requires preparation of briefings and program reports, both technical and administrative. Opportunities for active research participation are available, depending on area of technical expertise of applicant. The successful applicant will have a joint appointment in the academic department of the discipline of expertise.

Persons interested should submit a detailed resume together with the names of three references knowledgeable of the applicant's relevant experiences and expertise to Dr. Ray Askew, CCDS Director, Space Power Institute, 231 Leach Center, Auburn University, AL 36849-5320.

Initial consideration will be given to applications received by July 15, 1991. The position will be filled as soon thereafter as an acceptable candidate can be selected. Salary is dependent upon education and experience.

Auburn University is an AA/EQ Employer, welcoming applications from minority groups/women.

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1990, 367 pp., \$59.95.

Toolkit Intrinsic Programming Manual, Vols. 4 and 15, 2nd edition. *Nye, Adrian, and O'Reilly, Tim, O'Reilly & Associates, Sebastopol, Calif., 1990, 584 pp. and 764 pp. respectively, \$55 (for set).*

Surge Protection of Electronics. *Haskell Jr., Norman H., Continuing Engineering Education, Columbia, S.C., 1981, 165 pp., \$25.*

68000 Microcomputer Experiments: using Motorola educational computer board. *Wilcox, Alan D., Prentice-Hall, Englewood Cliffs, N.J., 1991, 304 pp., \$31.*

Programming Windows. *Petzold, Charles, Microsoft Press, Redmond, Wash., 1990, 944 pp., \$29.95.*

Digital Design, 2nd edition. *Mano, Morris M., Prentice-Hall, Englewood Cliffs, N.J., 1991, 516 pp., \$52.*

A Computer Perspective. *Eames, Charles, and Eames, Ray, Harvard University Press, Cambridge, Mass., 1990, 175 pp., \$9.95.*

Basics of Electron Optics. *De Wolf, David A., John Wiley & Sons, New York, 1991, 414 pp., \$49.95.*

Restoration of Lost Samples in Digital Signals. *Veldhuis, Raymond, Prentice-Hall, Englewood Cliffs, N.J., 1991, 138 pp., \$29.*

Principles of Modern Technology. *Melissinos, Adrian C., Cambridge University Press, New York, 1990, 337 pp., \$75.*

Introductory Electromagnetics. *Neff, Herbert P., Jr., John Wiley & Sons, New York, 1991, 414 pp., \$49.95.*

Solving Business Problems with MRP II. *Luber, Alan D., Digital Press, Boston, 1991, 333 pp., \$34.95.*

An Introduction to Applied Electromagnetism. *Christopoulos, Christos, John Wiley & Sons, New York, 1990, 183 pp., \$39.95.*

Fourth Generation Systems. *Holloway, Ed, Van Nostrand Reinhold, New York, 1990, 374 pp., \$72.95.*

Synchronization and Control of Distributed Systems and Programs. *Raynal, Michel, and Hély, Jean-Michel, John Wiley & Sons, New York, 1990, 124 pp., \$59.95.*

Quality Function Deployment: Integrating Customer Requirements Into Product Design. *Ed. Akao, Yoji, Productivity Press, Boston, 1990, 369 pp., \$75.*

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Contribute to an ongoing research effort focusing on R&D of speech technology for applications in telecommunications. Specific problem areas include continuous speech recognition, word spotting, statistical speech modeling and applications in degraded acoustical and electrical environments. Position requires ■ PhD in Electrical Engineering or related field with a strong background in theoretical and experimental aspects of speech processing and recognition. **Box BM.**

Electrical Engineers Telecommunications Systems Development

Several R&D positions are available to develop prototypes of advanced subscriber loop systems that bring broadband video, voice and data services to customers. In these positions, you will formulate system specifications, evaluate approaches to system architecture, design circuits, layout, fabricate and test subsystems, integrate subsystems into system prototype, and evaluate end-to-end system performance. MSEE or equivalent experience required and at least 5 years in communication systems R&D involving multiplexing techniques, fiber optic transmission or message signaling. **Box LU.**

Software Engineers Advanced Intelligent Networks

We have several positions available for experienced software designers and developers to join the advanced intelligent networks testbed project. For this project, you will design and develop prototypes of service creation environments, a service logic execution environment and operations support systems. We require an MS/PhD in CS/EE/Math as well as several years' experience in the following areas: UNIX® and Mach operating systems, C and C++ programming languages, Case tools, Motif and X-Windows, relational databases and real-time call processing. Knowledge of the telecommunications industry desired. **Box KT.**

Members of Technical Staff Computer & Network Security

We seek 2 nationally recognized experts to provide technical leadership in the areas of Computer Security and Network Security. For the Computer Security position, a thorough mastery of computer security certification and accreditation policies and issues is expected, especially the issues that arise at the B3 and A1 levels of trust. The Network Security position will play a leadership role in advising other GTE groups as to the appropriate strategies to be followed in better securing their networks. You will also conduct independent research to define and develop theories and concepts which will provide ■ measurable impact on future strategies and solutions. Both positions require ■ Master's/ PhD and 10 years' relevant experience. **Box RJ.**

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NANYANG TECHNOLOGICAL UNIVERSITY

Singapore

(To be established on 1 July 1991)

TEACHING APPOINTMENTS IN THE SCHOOL OF ELECTRICAL & ELECTRONIC ENGINEERING

In July 1991, the Nanyang Technological Institute (NTI) will be reconstituted and renamed the Nanyang Technological University (NTU). The new university will be a comprehensive university. It will conduct a wide range of courses at degree and postgraduate levels. Courses that are offered currently at NTI include Accountancy, Business, Computer Technology and Engineering (Civil, Electrical ■ Mechanical).

Applications are invited for academic appointments in the School of Electrical ■ Electronic Engineering from candidates who possess a higher degree in electrical, electronic and/or computer engineering and have at least three years of relevant industrial experience. Preference will be given to candidates with research/teaching experience in the following areas:

- | | |
|---------------------------------------|-----------------------------------|
| 1. IC Design | 6. Artificial Intelligence |
| 2. Thick/Thin Film Microelectronics | 7. Multiprocessor Systems |
| 3. Communication Networks and Systems | 8. Power Electronics |
| 4. Electronic CAD/CAM | 9. Instrumentation and Automation |
| 5. Avionics | 10. Energy Management |

The School of Electrical and Electronic Engineering has a current academic staff of 107 with 22 laboratories and workshops, all of which are equipped with excellent facilities for teaching and research.

The School has a wide range of modern and sophisticated equipment and instruments to support teaching and research in the fields of communications, computer, control, electronics, power and avionics ■ well as the abovementioned areas of research. Its Microelectronics Centre has 15 Apollo DN3000 Mentor Graphics CAD/CAM/CAE workstations, Gerber photoplotter, printers and necessary software for use in VLSI design. Also its Microprocessor Centre has a large universal microprocessor development system supporting 8, 16 and 32 bits as well ■ bit slice processors. A comprehensive range of computing resources are available, including powerful personal computer systems, microvaxes, IBM 5080, and SUN workstations. Facilities including Group III - V MBE system and ECR equipment as well as thick and thin film hybrid equipment are also available for research in the ■■■ of opto-electronics, fibre optics, LANs, digital signal processing, ISDN, computer and robotic vision and SCADA applications in power systems.

Gross annual emoluments range as follows:

Lecturer	I \$ 53,160 - S\$ 64,200
Senior Lecturer	: S\$ 58,680 - S\$100,310
Associate Professor	: S\$ 88,650 - S\$122,870
Professor	: S\$108,870 - S\$146,970

(US\$1.00 = S\$1.72 approximately)

In addition to the above, the Institute adopts the Government's practice in the payment of ■ variable bonus, the quantum of which is tied to national economic performance and has, in past years, ranged from 1 to 2⁷/8 months of December salary.

The commencing salary will depend on the candidates' qualifications, experience, and the level of appointment offered.

Leave and medical benefits will be provided. Depending on the type of contract offered, other benefits include: provident fund benefits or an end-of-contract gratuity of 25% of the staff member's last drawn monthly salary for each completed month of service, a settling-in allowance, subsidised housing, education allowance up to a maximum of S\$30,000 per annum, passage assistance, baggage allowance and car loan.

The Institute encourages its staff to undertake outside consulting work of ■ specialist nature. They are permitted to earn and retain such consultation fees up to a maximum of 60% of their gross annual emoluments in any one calendar year.

Further information on the above may be communicated to the Institute through BITNET to: TFWANG@NTIVAX

Candidates wishing to be considered should write to:

THE DIRECTOR
PERSONNEL DEPARTMENT
NANYANG TECHNOLOGICAL INSTITUTE
NANYANG AVENUE, SINGAPORE 2263

giving their curriculum vitae and the names and addresses of three referees.

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EMPLOYMENT OPPORTUNITIES

The following listings of interest to IEEE members have been placed by educational, government, and industrial organizations as well as by individuals seeking positions. To respond, apply in writing to the address given or to the box number listed in care of *Spectrum Magazine*, Classified Employment Opportunities Department, 345 E. 47th St., New York, N.Y. 10017.

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IEEE encourages employers to offer salaries that are competitive, but occasionally a salary may be offered that is significantly below currently acceptable levels. In such cases the reader may wish to inquire of the employer whether extenuating circumstances apply.

Academic Positions Open

The Department of Electrical Engineering at Tulane University has an opening starting in the Fall 1991 semester, for a full-time, tenure track faculty position. Duties include teaching graduate and undergraduate courses, research, and advising students. Rank and salary are commensurate with qualifications. Requirements: Doctorate in Electrical Engineering with ■ specialty in power or must have completed all requirements for this degree except dissertation within the year prior to selection, with expected completion of dissertation prior to inception of employment. Complete vitae with a minimum of three references should be sent to Dr. S.T. Hsieh, Department of Electrical Engineering, Tulane University, New Orleans, LA 70118-5674, (504) 865-5785. All candidates should indicate citizenship and, in the case of non-US citizens, describe their visa status. Tulane University is ■ equal opportunity/affirmative action employer.

The Department of Electrical Engineering at the University of Kentucky invites applications for an anticipated tenure track faculty position in the area of power electronics, for appointment on July 1, 1991. The applicant should hold an earned Doctorate in Electrical Engineering and have ■ sincere interest in research and teaching at both the undergraduate and graduate levels. Although applicants with interest in any aspect of power electronics will be considered, preference will be given to individuals with specialty in either high-speed switching applications in adjustable speed drives or switched-mode power supplies. The ideal candidate should also have interest in microprocessor and DSP controls applied to power electronics problems. This newly established faculty position offers a unique opportunity for a qualified and energetic person to build his/her own research program and course offerings to complement and extend an already established activity. Qualification to seek extramural funding from both industry and government agencies is expected. Interested individuals are invited to send a letter of application, a resume, and a list of three references to Dr. S.A. Nasar, Chairman, Department of Electrical Engineering, University of Kentucky, 453 Anderson Hall, Lexington, KY 40506-0046. Women and minorities are en-

couraged to apply. The University of Kentucky is an equal opportunity and affirmative action employer.

Knight Chair in Biomedical Engineering. The Biomedical Engineering Department, University of Miami, invites nominations and applications for its new Knight Chair in Biomedical Engineering. It is expected that candidates will have an outstanding reputation in research, an established record in external funding, and ■ commitment to education. A person is sought who would establish a strong research link with some branch of the University of Miami School of Medicine. The Department offers M.S. and Ph.D. programs and undergraduate options in other branches of engineering. The University is located in beautiful Coral Gables, within the Miami metropolitan area. Nominations and applications with the names of three referees should be sent to Dr. Eugene Eckstein, Biomedical Engineering Dept., PO Box 248294, University of Miami, Coral Gables, FL 33124-0621. The University of Miami is an Equal Opportunity/Affirmative Action employer.

Endowed Chair in Electrical Engineering at Georgia Tech. The Georgia Institute of Technology is seeking candidates for the Joseph M. Pettit Chair in the School of Electrical Engineering. Applications and nominations for this endowed chair are now being accepted. It is expected that the chair holder will play a principal role in the definition and development of future programs in the ■ of computer engineering and/or closely related areas. Candidates must have ■ record of distinguished performance and well established potential for providing leadership in research and instructional program development. Salary and program development funds available for support of this distinguished position are fully competitive. Resumes and nominations should be submitted by September 2, 1991 and addressed to: Director, School of Electrical Engineering, Georgia Institute of Technology, Atlanta, GA 30332-0250. Georgia Tech is an equal opportunity, affirmative action employer.

Washington University seeks qualified candidates for the position of Professor and Chair of the Department of Systems Science and Mathematics, with a desired starting date of July 1, 1992. We are interested in outstanding candidates with ■ strong research record, with a dedication to excellence in undergraduate and graduate education and with ■ demonstrated potential for administration and leadership. Washington University has a long standing commitment to the principle that all candidates should be afforded equal opportunity regardless of age, race, sex or physical disability. Candidates must send ■ curriculum vitae and a list of references to: Professor C.I. Byrnes, Search Committee for the Systems Science and Mathematics Chair, Campus Box 1040, Washington University, One Brookings Drive, St. Louis, MO 63130.

Faculty Position—Applications are invited for a tenure-track position in the ■ of Computer Engineering in the Department of Electrical and Computer Engineering at the University of Victoria. The position will involve undergraduate and graduate teaching, graduate supervision at the master's and doctoral levels, and research. We seek applicants who can add to our existing strengths in parallel and distributed systems, systems and applications, VLSI systems design, or in related areas of computer engineering. Applicants should hold a doctorate. Industrial experience and registration as ■ Professional Engineer in Canada will be considered as assets. The Department of Electrical and Computer Engineering at the University of Victoria was established on July 1, 1983 and is housed in attractive ■ buildings. The Department offers accredited undergraduate programs leading to the B.Eng. degrees in electrical engineering and computer engineering, and graduate programs leading to the M.Eng., M.A.Sc., and Ph.D. degrees. The Department is very active in research with an annual research

budget in excess of 1.8 M\$. The departmental facilities include over 30 SUN workstations interconnected via ethernet, and modern equipment for research in computer engineering. These include several expert system development environments, design and testing facilities for VLSI and gate arrays, as well as facilities for research in neural networks and image processing. The Department participates in all three national Networks of Centres of Excellence in engineering. The faculty strength has recently increased to 18 full-time members. Victoria is situated at the southeastern tip of Vancouver Island and is well known for its superb climate and flowers. In accordance with Canadian Immigration regulations, this advertisement is directed to Canadian citizens and permanent residents of Canada. If no suitable candidates are found, the search may be extended to other candidates. The University of Victoria is committed to an employment equity plan. Women ■ especially encouraged to apply. Applications, which should include a curriculum vitae and the names of at least four referees, should be addressed to: Chair, Dept. of Electrical and Computer Engineering, University of Victoria, P.O. Box 3055, Victoria, B.C., Canada V8W 3P6

Electrical Engineering Technology. Opening for Assistant Professor or Associate Professor starting January 2, 1992 (pending funding). Minimum requirements: B.S. and M.S. in EET, EE or related field and three years of relevant engineering experience. Professional registration will be required for tenure. Teaching experience desirable. Expected to teach TAC/ABET accredited Associate and Baccalaureate courses in one or more of the following areas: (1) Industrial controls and power electronics; (2) Digital electronics and microprocessors; (3) Linear electronics and communications; and (4) Power systems and machinery. Position is open until filled. Rank and salary will be commensurate with qualifications. Send resume with names and addresses of three references to: John McDonough, Director, School of Engineering Technology, 221 East Annex, University of Maine, Orono, ME 04469. The University of Maine is an Equal Opportunity/Affirmative Action employer.

Research Engineer in Electromagnetics. The Telecommunications Research Center, College of Engineering and Applied Sciences, Arizona State University, is seeking a tenure-track research engineer at the assistant or associate level in the area of applied electromagnetics. This engineer will be involved in applied electromagnetics research primarily for the analysis and computer code development for antennas and radar cross section of complex structures. Applicants must have an earned doctorate in Electrical Engineering, with expertise in electromagnetic theory, antennas, scattering, expert knowledge and applications of Geometrical Theory of Diffraction and/or Moment Method, and proficiency in Fortran. The successful applicant will be affiliated with the Telecommunications Research Center, ■ center for research excellence. The University has both ■ Cray XMP-18/se and an IBM 3090-500/MV computer, and a spacious and state-of-the-art ElectroMagnetic Anechoic Chamber (EMAC) with a compact range for antenna and RCS measurements. Please send letters of applications, resumes, and the names of three references to: Dr. Constantine A. Balanis, Director, Telecommunications Research Center, Arizona State University, Tempe, AZ 85287-7206. The first deadline is June 30, 1991, or the 15th of each month until the position is filled. Arizona State University is ■ equal opportunity, affirmative action employer.

The ECE dept., Univ. of Michigan-Dearborn, seeks an experienced candidate with PhD. at the Asst./Assoc. Professor level starting Fall 1991. Specialties sought in the area of computer engineering, including Computers and Digital Systems, Computer Vision and Machine Intelligence, Integrated Circuits and VLSI. Send resumes to: Chairman, ECE dept., Univ. of

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EMPLOYMENT OPPORTUNITIES

Michigan-Dearborn, 4901 Evergreen Road, Dearborn, Michigan 48128. U of M is an equal opportunity educator and employer and specifically invites and encourages applications from women and minorities.

The University of Oklahoma, School of Electrical Engineering and Computer Science, invites applications for one open tenure track position in our Electrical Engineering program. All applicants must hold ■ Ph.D. in electrical engineering, computer engineering or a closely allied field. Industrial or teaching experience is desirable. All areas of expertise in electrical engineering will be considered as long as the candidate has ■ strong commitment to teaching at both the undergraduate and graduate level and to the development of a research program. Consideration of applicants will begin June 1, 1991, and will remain open until the positions are filled. Send vita with three references to T.E. Batchman, Director, School of Electrical Engineering and Computer Science, 202 West Boyd, Room 219, Norman, OK 73019. The University is an equal opportunity/affirmative action employer. Women and minorities are encouraged to apply. OU has a policy of being responsive to dual-career couples.

The Department of Electrical Engineering at Colorado State University is seeking candidates for the Rockwell Optoelectronics Faculty position. This new position will be supported by industry, private endowments, and the University. The position will be a tenured or tenure-track appointment within the Department. We anticipate that the appointment will be for an individual who has recently established an outstanding record of research accomplishments in optoelectronics or a new graduate who shows exceptional promise. Candidates are sought in the areas of optoelectronic semiconductor materials and devices and in optoelectronic systems, with emphasis on practical implementation of telecommunication or optical computing systems. The position will be affiliated with the Center for Optoelectronic Computing Systems (an NSF Engineering Research Center jointly operated with the University of Colorado at Boulder). The new faculty member is expected to develop a major research program both through interaction with the existing programs in optical and electronic materials and devices as well as by development of new areas. Applicants should have an earned Ph.D., demonstrated research ability, and a strong interest in undergraduate and graduate teaching. Applicants should submit a detailed resume with a statement of their professional interests and goals, along with the names of three references. Applications will be accepted until August 31, 1991. This deadline may be extended if suitable candidates are not found. Additional information describing the applicant's work, such as papers or technical reports are welcomed. Please send all application materials to: Professor Jorge I. Aunon, Department of Electrical Engineering, Colorado State University, Fort Collins, CO 80523. (303) 491-6600 Fax (303) 491-2249, Email: aunon@longs.lance.colostate.edu. Colorado State is an EEO/AA employer. Office: 314 Student Services Building.

Teaching Associate and Tenure Track Assistant Professor Positions. University of Missouri-Rolla seeks applicants for 1991-1992 teaching associate (M.S. required) and tenure track assistant professor (Ph.D. required) positions. Only applicants in computer engineering or control systems will be considered. Permanent residency or U.S. citizenship is essential at the time of employment. Please send resume and the names of three references to: W.J. Gajda, Jr., Chairman, Department of Electrical Engineering, University of Missouri-Rolla, Rolla, MO 65401. Application deadline is October 15, 1991. The University of Missouri is an Equal Opportunity/Affirmative Action Employer.

Faculty Position—University of New Brunswick, Department of Electrical Engineering. The Department of Electrical Engineering invites applications for ■ tenure-track Assistant

or Associate Professor position in the area of electric machines, power systems and electric circuits. The position involves research and teaching at both the undergraduate and graduate levels. Applicants should have completed or be near completion of the PhD in electrical engineering at the time of appointment, be eligible for registration as a professional engineer in the Province of New Brunswick, and have a strong commitment to teaching and research. Applications with a curriculum vitae and the names and addresses of three referees should be sent to: Dr. Philip A. Parker, Department of Electrical Engineering, University of New Brunswick, P.O. Box 4400, Fredericton, NB, E3B 5A3. In accordance with Canadian Immigration requirements, this advertisement is directed to Canadian Citizens and permanent residents of Canada. The University of New Brunswick is committed to the principle of employment equity. The position is subject to final budgetary approval, and is expected to be filled by Sept. 1, 1991.

The Department of Physics and Astronomy at the University of Wyoming is seeking to fill one Engineer I (electrical) position. A degree in electrical engineering or equivalent experience is required. The successful candidate must be skilled with design and construction of compact battery operated electronics for remote use. Must have demonstrated ability in high reliability soldering and construction and repair of high reliability circuits; willing to travel to remote sites, work some evenings, weekends and holidays when necessary to complete projects. The salary range is \$19,212-\$22,008 per year. Interested applicants should apply to University of Wyoming Personnel Services, Box 3422, Laramie, WY 82071. Applications postmarked no later than June 26, 1991 will be considered. Anticipated hiring date is July 1, 1991. The University of Wyoming is an Equal Opportunity/Affirmative Action employer.

School of Engineering and Applied Science—UCLA Announces The Northrop Professorial Chair in Electrical Engineering. The UCLA school of Engineering and Applied Science is conducting a search for an appointment to the Northrop Professorial Chair in Electrical Engineering/Electromagnetics. Applications are invited from academic, governmental, and the private sector. The person appointed to this chair will be a distinguished scholar who has performed outstanding research in the science and technology in the areas of electromagnetics. In addition, he or she will have a strong commitment to education and an interest in working with the electromagnetic industry and government. The research focus of the incumbent shall be in electromagnetic engineering, including scattering, diffraction, electromagnetic interaction with materials, computational and theoretical electromagnetics, guided wave theory and asymptotic theory. Preference will be given to a leader who will bring about new engineering applications of electromagnetics. Rank and salary will be commensurate with experience and qualification. Nominations and applications, ■ complete resume, and the names and addresses of five references, should be sent to Professor T. Itoh, Chairman, Search Committee for the Northrop Chair in Electrical Engineering, Department of Electrical Engineering, 66-147A Engineering IV, University of California, Los Angeles, California 90024. UCLA is an Equal Opportunity Affirmative Action Employer.

University of Illinois at Urbana-Champaign. Applications and nominations are invited for the Grainger Professorship in Electrical and Computer Engineering at the University of Illinois at Urbana-Champaign. The Grainger Professorship has been endowed by The Grainger Foundation, Inc. in honor of Mr. W.W. Grainger who graduated from the College of Engineering in 1919. The appointment will be at the rank of professor with tenure in the Department of Electrical and Computer Engineering. The department solicits applications from distinguished senior engineers with expertise and research interests in any of the following or related areas: power systems, manufacturing, robotics, intelligent systems, control systems, and rotating machinery. Applicants must have an earned Ph.D., outstanding qualifications, and an ability to teach effectively at both the graduate and

undergraduate levels. Selected candidates will be expected to initiate and carry out independent research and to perform academic duties associated with our B.S., M.S., and Ph.D. programs. Starting date is negotiable. Salary open, based on qualifications. Send resume, with references and ■ list of publications to: Professor Chester S. Gardner, Chair, Grainger Professorship Search Committee, University of Illinois, Department of Electrical and Computer Engineering, 1406 W. Green Street, Urbana, IL 61801. (217) 333-2300 The deadline for receipt of application materials to receive full consideration is September 15, 1991. The University of Illinois is an Affirmative Action, Equal Opportunity Employer.

Chairholder, Noranda/NSERC Industrial Chair in Mining Automation. Ecole Polytechnique de Montreal invites nominations and applications for candidacy for the Noranda/NSERC industrial chair in Mining Automation. Candidates with experience in automation, robotics, computer vision or underground communications would be of particular interest. Mining experience would be an asset. The candidate should hold a Ph.D. degree in either mining engineering, electrical engineering, mechanical engineering, engineering physics, or the equivalent. He/she must be capable of providing leadership in collaborative research with industry and of contributing significantly to the research activities and supervision of graduate students. The chair will require its holder to lead researchers and graduate students involved in the automation of mining equipment. The research work of the candidate will relate to some of the following fields: automatic guidance, artificial vision, remote control techniques and monitoring, development of new sensors or adaptation of existing ones to mining applications, and underground communications. The objective of his/her research should aim at the development of concepts leading to new mining technology. Applicants and nominees must have an outstanding research record, a strong interest in teaching and a commitment to the creation and development of a world class research program in mining automation. The chairholder will work closely with CCARM (Canadian Center for Automation and Robotics in Mining) researchers. CCARM, which was jointly created by Ecole Polytechnique and McGill University in 1988, is strongly involved in applied research in mining automation. This new chair is sponsored by Noranda Inc. and the Natural Sciences and Engineering Research Council of Canada (NSERC); both will participate in the evaluation process of candidates. The chairholder will hold ■ tenure track position at Ecole Polytechnique, normally at the level of full professor. A working knowledge of French is desirable. Interested persons should write to Mr. Rene Dufour, Professor, Mineral Engineering Department, Ecole Polytechnique, P.O. Box 6079, Station A, Montreal, Quebec, Canada H3C 3A7, tel.: (514) 340-4926, fax: (514) 340-4477. Applications will be accepted until September 3, 1991. In accordance with Canadian immigration requirements, priority will be given to Canadian citizens and permanent residents of Canada. Ecole Polytechnique is an equal opportunity employer.

Dean, School of Engineering. University of Alaska Fairbanks. The University of Alaska Fairbanks invites applications for the position of Dean of the School of Engineering. The University of Alaska Fairbanks is the land, sea and space grant campus of the University of Alaska system and the major center of science and engineering research and education. The School of Engineering encompasses three undergraduate academic units (civil, electrical and mechanical engineering) and offers graduate degrees in these disciplines ■ well as arctic engineering, environmental quality engineering, environmental quality science, engineering management, and science management. The Institute of Northern Engineering, with an annual research budget in excess of two million dollars, is the research arm of the School and is comprised of the Water Research Center, the Transportation Research Center and the Engineering Research Center. Enrollment at the School of Engineering currently includes 350 undergraduate majors and 60 full-time graduate students with 30 full-time faculty. The Dean provides leadership to the faculty and is

the chief administrator of the School of Engineering and the Institute of Northern Engineering. The Dean is also responsible for facilitating interactions with other colleges, professional schools and research entities. The UAF campus overlooks Fairbanks, a thriving community of 72,000, rated fourth best small community in the nation. Fairbanks offers outstanding cultural diversity, unsurpassed natural beauty and outdoor recreation, and a friendly local atmosphere. Fairbanks is a transportation hub served by major airlines. Public and private schools in Fairbanks have an excellent reputation. Candidates for this position should have the following qualifications: —Earned doctorate, a significant record of both scholarly achievement and sustained research activity sufficient for appointment at the rank of Professor in one of the departments of the School (professional engineering registration is a consideration); —Ability to build and maintain strong academic programs and recruit outstanding faculty and students; —Experience in academic and research administration; —Strong communications and human relations skills; —Vision and capability to successfully develop academic and research opportunities in engineering. Send curriculum vitae; statement of interest; and names, addresses, and phone numbers of five references to: Professor Douglas L. Kane, Chair, SOE Dean Search Committee, Water Research Center, School of Engineering, University of Alaska Fairbanks, Fairbanks, AK 99775-1780. Phone (907) 474-7808, FAX (907) 474-6087. Screening of applications will begin 15 July 1991. The anticipated starting date for the position is October/November, 1991. The University of Alaska is an Affirmative Action, Equal Opportunity Employer and educational institution.

Electrical and Computer Engineering: The Department of Electrical and Computer Engineering at Rose-Hulman Institute of Technology invites applications for a tenure track or visiting faculty position in the areas of Energy Conversion and Power Systems. Seeking PhD with strong commitment to and experience in undergraduate/graduate education. Successful candidate should exhibit superior teaching skills in dealing with small classes of well-qualified students. S/he should expect to become involved in the growing area of undergraduate research. Research is considered important but is viewed as only one of many avenues toward the goal of on-going professional development. Appointment will be commensurate with experience and qualifications. Candidates should send current curriculum vita and the names of three academic references to: Dr. Buck F. Brown, Chairman, Department of Electrical and Computer Engineering, Rose-Hulman Institute of Technology, 5500 Wabash Avenue, Terre Haute, Indiana 47803.

University of California, Berkeley, Institute of Transportation Studies, Program on Advanced Technology for the Highway. Research Position Available. Specialist—The Institute of Transportation Studies is seeking a researcher for a position in its Program on Advanced Technology for the Highway (PATH), a major research program in the field of intelligent vehicle/highway systems (IVHS). It involves research, development, and testing of advanced technologies for highway transportation, including automation, advanced information and management systems, and clean propulsion technologies. Duties and Responsibilities: The incumbent will be responsible for leading a major research and development effort on automatic steering control of road vehicles, involving work with faculty, student and full-time staff researchers and cooperating engineers from private industry. The work involves development of reference/sensing techniques, and theoretical analysis of safety and reliability-related issues for maximizing safety of the lateral control system. In addition to conducting original research, he or she will also be involved in defining research goals and objectives, milestones and schedule priorities and responsibilities. He or she will have management authority over project staff researchers and will serve as the contact person with the private industry partner(s) in the project. Qualifications: This position requires a minimum of a Master's degree in Electrical Engineering plus at least five years applicable experience and some project leadership ex-

perience. The applicant's experience must include knowledge of technologies of automated lateral guidance of road vehicles and expertise in sensing (particularly electromagnetic sensing) and signal processing technologies. The applicant should also demonstrate analytical and experimental expertise in engineering of systems for maximum safety (including formal safety analysis, Fail-Safe and Fault-Tolerant system design). The applicant must have good communication skills, both oral and written. Salary Range: \$49,716-76,860 per year, salary to be determined depending on qualifications and experience. Start Date: Approximately July 1, 1991. Initial appointment for 3 years; reappointment subject to availability of extramural funds. To Apply: Send curriculum vitae and the name/address of three references to: Director, Institute of Transportation Studies, 109 McLaughlin Hall, University of California, Berkeley, CA 94720. Please refer to job number: ITS-36. Deadline: May 31, 1991 or 30 days from the publication of this advertisement, whichever is later. The University of California is an Equal Opportunity, Affirmative Action Employer.

The Department of Electrical Engineering, Stanford University, invites applications for a faculty position for research and teaching in superlattice and quantum well semiconductor optoelectronic devices. Applicants should have a strong background in device physics and application of novel concepts of artificially structured materials, quantum wells and superlattices to optoelectronics. Candidates for this leadership faculty position will be considered for a position beginning in September 1991. Stanford University is an Equal Opportunity Employer and welcomes applications from women and minority groups. Please submit as soon as possible, detailed resumes, publications list and names of five references to Professor James Harris, Director, Solid State Electronics Laboratory, Department of Electrical Engineering, Stanford University, McCullough 226, Stanford, CA 94305.

University of Hawaii at Manoa, Department of Electrical Engineering, invites applicants for tenure-track associate professor or assistant professor positions with specialization in the areas of: (1) Computers: System software, parallel and distributed algorithms, and computer networking. (2) Electrophysics: Microwave engineering and VLSI engineering. (3) Communications: Data networks. Duties: Teach EE undergraduate and graduate courses, serve on university and department committees, serve on graduate student committees, conduct research and scholarly activities, and perform related tasks as assigned. Minimum Qualifications: Associate Professor: Ph.D. degree or completion of all requirements for a doctorate in electrical engineering, computer science, and/or equivalent; minimum of four years of full-time college or university teaching at the rank of assistant professor or equivalent, with evidence of increasing professional maturity; demonstrated scholarly achievement in comparison with peers active in the same field; demonstrated ability to plan and organize assigned activities, including the supervision of work of assistants when appropriate; ability to pursue and supervise research; strong commitment to both undergraduate and graduate teaching. Assistant Professor: Ph.D. degree or completion of all requirements for a doctorate in electrical engineering, computer science, and/or equivalent; demonstrated ability to teach; demonstrated scholarly achievement; ability to pursue and supervise research; strong commitment to both undergraduate and graduate teaching. Salary negotiable dependent upon qualifications and experience. Send resume and three references by July 15, 1991 to: Professor Shu Lin, Chairman, Dept. of Electrical Engineering, University of Hawaii at Manoa, 2540 Dole Street, Holmes Hall 483, Honolulu, HI 96822. An Equal Opportunity/Affirmative Action Employer.

The Center for High Technology Materials (CHTM) at the University of New Mexico invites applications for a tenured/tenure track faculty position in Optoelectronics. The specific area of expertise desired is metal organic chemical vapor deposition (MOCVD) of III-V compound semiconductor materials. The successful appli-

cant will work with an existing growth group and other optoelectronics faculty to design growth processes for new optoelectronic devices and would also be expected to establish an independent research program. CHTM presently has one state-of-the-art MOCVD machine and is in the process of acquiring a second one. On-going research in the Center includes vertical cavity surface-emitting lasers, laser diode arrays, visible laser diodes, and high efficiency semiconductor laser pumps for solid-state lasers. Rank and salary will be commensurate with qualifications and experience. Send resume and list of three (3) references to: Dr. Brueck, Director of CHTM, University of New Mexico, Albuquerque, NM 87131, before August 1, 1991. The University of New Mexico is an Equal Opportunity/Affirmative Action Employer.

Electrical Engineering: Catholic University, Washington, DC; applications are invited for two tenure track positions in the Department of Electrical Engineering. The first position is in the area of communication systems. For this position the candidate must have a doctoral degree in Electrical Engineering with a proven record of teaching and research. The candidate will take an active role in the development of our research program in communications. The second position is at the Assistant Professor level in one of the following areas: signals and systems, microwaves, optical engineering, or computer hardware. For this position the candidate must have a doctoral degree in EE, interest in teaching and a potential for developing a research program. Both positions are available for Fall 1991. US citizenship or permanent residency is required. Send resume to Prof. M. Arozullah, Department of Electrical Engineering, The Catholic University of America, Washington, D.C. 20064. (Tel. # 202-319-5193). CUA is sponsored by the Roman Catholic Bishops of the U.S. as a national university and is an equal opportunity/affirmative action employer.

Government/Industry Positions Open

Engineering. Planarization Engineer. Responsible for wafer cleaning, planarization, and otherwise maintaining the reliability of electronic devices. Duties include: monitoring, controlling, and reducing particulates on silicone wafer surfaces; developing and improving wafer cleaning technology and making this technology production-worthy; and participating in the manufacture of the P650 planarization process. Academic project/research background in materials science and engineering, electrical package principles, and integrated circuit technology. Must be familiar with Lotus software; Measures software; SAS, RS1, and RS Explorer; WordPerfect; VAX; and Workstream, CEPTS, and COMETS. Experience in cleaning silicon wafers, and advanced knowledge of the electrokinetic characteristics of wafer liquid interface, contamination control, and process engineering preferred. Position requires a PhD in Materials Science and Engineering. \$4250/mo.; 40 hrs./wk. Place of employment and interview: Rio Rancho, NM. If offered employment, must show legal right to work. Clip ad and send resume to: Job No. S418, P.O. Box 58119, GRI-57, Santa Clara, CA 95052, not later than June 10, 1991. The company is an equal opportunity employer and fully supports affirmative action practices.

Software Engineer. We are a rapidly growing network company in the Twin Cities and are seeking top notch software engineers to join our Research and Development staff. Our products provide a platform for distributed applications to execute over both mobile (wireless) and fiber/wire-based (stationary) networks via OSI communications protocols. As a key contributor to our company you will develop LAN and WAN protocols, network management software and gateways for our core products. Opportunities also exist for you to port our products to different computer and operating systems and develop tools for application users and system engineers. Individuals are sought for both junior and senior positions who have a BS/MS in CS, 4-10 years of experience and expertise in using C with DOS, UNIX, or OS/2.

Classified

EMPLOYMENT OPPORTUNITIES

Knowledge of network communications protocols (OSI, TCP/IP for IPX), network management or windows managers is a definite plus. We offer competitive salaries and an excellent benefits package. Send resume to: V.P. Research and Development, Racotek Inc., 501 E Hwy 13, Burnsville, MN, 55337.

Systems Design Software Engineer. Responsible for technical plan and design of new software applications for the health care industry to provide graphical user friendly interfaces. Make recommendations concerning which hardware platforms to use. Plan which Windows packages and other development tools to use with C programming language on the Unix Operating System, especially Sun Os. Oversee the design and implementation to achieve efficient operation and to optimize performance. Minimum requirements: B.S. in Computer Science or Computer Engineering; 2 years experience developing graphical user friendly applications system software under Windows in C programming language for the Unix Operating System; 6 months experience designing user friendly applications and interfaces under Windows, including 3 months X Window experience writing software, which may be concurrent experience. \$42,500 per year. 40 hr. week. Submit resume to Colorado Department of Labor and Employment, 600 Grant Street, Suite 900, Denver, CO 80203-3528. Refer to Order No. CO3195353.

Supervisory Electronics Engineer needed for company in Boulder, Colorado specializing in R&D and engineering support for Space Systems Division. Conduct and manage ongoing research and development involved in design, manufacture, and testing of electronic components used in the construction of satellites and other related tracking devices. Manage all mechanical and electrical construction tasks, including design, implementation, and verification of analog, digital and RF circuit systems. Use CAD and CAE techniques, using PCs and LAN equipment. Manage technical staff. Requires MS or equivalent (BS+3 years experience). Electronics Engineering; 1 year in design, implementation, and verification of analog, digital and RF circuits and systems. \$36,000/year; 8:00am-5:00pm, M-F. Respond by resume to Colorado Department of Labor & Employment, Division of Employment & Training, 600 Grant, Suite 900, Denver, CO 80203, ATT: Phil Minjarez, and refer to Job Order No. CO3195420.

Research Associate and Post-Doc Positions in the area of Electronic Materials. Kobe Steel Research Laboratories, USA—Electronic Materials Center, located in Research Triangle Park, NC, has openings for Research Associates and Post-docs. The Electronic Materials Center is a division of Kobe Steel Ltd. of Japan chartered to research electronic devices based on diamond thin films. Insulator/dielectric Deposition—BS or MS in EE, Mat. Sci., Physics, or related field; experience in insulator deposition and characterization; and proven record in independent research. (Contact: Dr. David L. Dreifus, Research Scientist). Metallization—BS or MS in Materials Science, Physics, or or related field; experience in PVD; and proven record of independent research. (Contact: Mr. Dale G. Thompson, Lab Oper. Manager/Researcher). Post-doc Ion Implantation—Strong Physics, EE or Mat. Sci. background. Thesis study in implantation and experience in electrical characterization. (Contact: Dr. Kumar Das, Research Scientist). Full consideration given to recent graduates. Salary based on experience. Direct resumes to (Contact), P.O. Box 13608, Research Triangle Park, NC 27709.

Electrical Engineer in charge of designing software and hardware for automated testing equipment to be used to test aircraft electrical systems; 40 Hr. work week; 9:00 a.m. to 5:00 p.m., Monday—Friday, will supervise three (3) employees; \$27,000.00 annual salary; minimum education—Bachelor of Science Degree in Electrical Engineering. The job location is in Miami, Florida. Send resume only to: Job Service

of Florida, 701 S.W. 27th Avenue, Room #15, Miami, Florida 33135. Ref: Job Order No. FL-0409496.

Production Eng: Test 900 MHz radio, dev RF testing, quality procedures, and specialized automation req SMT and MODICON Controller exp. MSEE and 4 yrs radio based product experience. \$42,500/an. Send resume: Colo. Dept. of Labor and Employment, 600 Grant Street, Suite 900, Denver, CO 80203-3528. Ref order CO3195402.

Postdoctoral Appointee—MAGLEV. Argonne National Laboratory. The Energy Systems Division of Argonne National Laboratory seeks a Postdoctoral Appointee to assist in the design of maglev vehicle and guideway concepts and laboratory-scale models; conduct measurements of parameters associated with suspension, guidance, propulsion, and damping of motions of magnetically levitated scale model vehicles; and compute and compare results using 2- and 3-dimensional models. Appointment requires a new or recent Ph.D. in Electrical Engineering or Physics. Also essential are: good working knowledge of Maxwell's equations; experience with codes use to compute magnetic fields, induced eddy currents and field-current interactions; laboratory experience in designing, setting up, and operating experiments in electromagnetism, including use of standard electrical and electronic equipment, instruments, and data acquisition systems. Familiarity with magnetic levitation and related experimental methods is desirable. For prompt consideration, send detailed resume to: Susan Walker, Box J-ES-89061-33, Employment and Placement, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, IL 60439. An equal opportunity/affirmative action employer.

Electrical and Computer Engineers—Fish & Neave is a nationally known intellectual property law firm of over 100 lawyers located in midtown Manhattan. We are seeking graduate students or practicing engineers, preferably with advanced degrees, in the areas of electrical engineering and computer technology who are interested in the field of patent law for our Patent Agent Trainee program. We offer full-time employment, in which we train the individual to prepare and prosecute patent applications and perform other tasks relating to our practice, including litigation, while attending night law school in the New York City area. Salary: Not less than \$55,000/yr. Benefits: Full law school tuition; full medical benefits; four weeks paid vacation. Send resumes to Deirdre M. Rogan, Recruitment Coordinator, Fish & Neave, 875 Third Avenue, New York, NY 10022-6250.

Research—Computer: Conducts applied research in storage tech. (tape & disk drives) & recording physics w/particular emphasis on nanometer scale surface interactions for tribology issues in storage. Conducts research on surfaces using Scanning Tunneling Microscopy (STM), Scanning Force Microscopy, (SFM), scanning probe techniques & other surface analysis tools to analyze & devlp. models for wear phenomena in contact recording. Duties include microfabricated device modeling for thin film storage heads & other storage related devices as a function to wear & surface structure, design of electronics, mechanical parts as well as software & surface characterization related instrumentation. Req'd: Ph.D. in E.E. & knowledge on nanometer scale surface science, surface characterization & surface modification w/STM or SFM scanning probe microscopy techs. Demonstrated knowl. of microfabricated device modeling; design & devlp. of instrumentation & measurement techniques including signal & image processing, data acquisition & control software, ultra-high vacuum systems, electronics design, & mech. design. Above knowledge must be demonstrated by relevant publications. 40 hrs/wk; \$57,000/yr. Job & interview site: San Jose, CA. Send this ad and your resume to Job # GB 27004, P.O. Box 9560, Sacramento, CA 95823-0560 not later July 10, 1991. EOE.

Scientist, Fiber Optic Gyroscopes—Develop and define theoretical models capable of predicting the performance of fiber optic gyroscopes. Requires Ph.D. Electrical Engineering, with emphasis in fiber optics and lasers. Ph.D.

program must have included experience in design of optic experiments, polarization effects in optical fiber, fiber optics components, laser theory & different laser systems including superluminescent and other broadband light sources, analysis of wave guide and integrated optic structures in LiNbO₃. Pay is \$1,098/wk. Job site and interview, Woodland Hills, CA. Send resume and copy of this ad to Job# WS12137, P.O. Box 9560, Sacramento, Ca 95823-0560, no later than 30, June, 1991.

Proj Mgr—40hrs/wk, Mon-Fri, \$3330/Mo. To manage I/E DCS Projects-resp for Eng & Costs. 5 yrs exp + 5 yrs rel exp in Cost Cntrl, Estimating & Scheduling. Res to 7310 Woodward Ave, Rm 415, Detroit MI 48202-Ref #96990. Some Rel Ass may apply.

Senior Engineer needed to design, analyze and implement Common Channel Signaling Networks using telephony and digital switching design; initiate and conduct research to develop new products which enables common channel signaling network access and new services including Multi-Service Database, Line Information Database, Alternative Billing Service, and System for Effectively Eliminating Customers Uncollectible Revenue; perform protocol design and Application Script development for new products and services; develop the Project Plan necessary to implement product(s) and service(s) into the network; interfaces with vendors, network engineers, database engineers, technical consultants, independent telco engineers, and other client company technical personnel; reduces dependency on outside consultants for needed telephone engineering and technical experience. Minimum Requirement: Bachelor of Science degree in Electrical Engineering and 6 years experience in job offered or 6 years experience in engineering position in telecommunication industry to include 3 years in common channel signal network, 2 years in telephony network and digital switching design and 1 year in protocol design. 40 hours work week. \$57,000 per year. Job located in Olympia, WA. Send resumes by July 1, 1991 to Employment Security Department, E.S. Div., Job No. 001033-M, Olympia, WA 98504. Must have proof of legal authority to work permanently in U.S.

Systems Engr.—Arch. design & research of Asynchronous Transfer Mode (ATM) & photonic switches & fault-tolerant rearrangeable intercon. netwk; system study of congestion control, buffer mgmt & traffic scheduling using queuing & sampling theories, stochastic process & combinatorial; protocol & arch. des. of Integrated Svcs. Digital Netwk (ISDN) & common channel signaling; simulate B-ISDN & ATM switch using C, Fortran, UNIX, graph theory & parallel programming; test hardware & design of ATM switch components using CAD tool & test equipmt. Rqmts: Ph.D. in Electrical Eng. & 6 mo. exp. as Systems Engr. or 6 mo. exper. as Test Engr or Research Asst in Electrical Eng. field. M-F, 40 hr/wk, 8:30-5:00; \$49,000-54,000/yr. sal. range; mail resume & copy of ad to MD DEED, 1100 N. Eutaw St., Rm. 212, Balt., MD 21201; JO# 9047885; Job location: Clarksburg, MD; Proof of legal right to work in U.S. required.

Electronics Engineer for research and development in new statistical techniques for design for manufacturability in the TCAD department of Advanced Technology Center; develop methodologies for the electrical characterization of silicon devices & apply these methodologies to establish & verify new statistical IC design tools; develop physics-based models to relate final electrical performance of ICs to initial IC processing conditions applicable to new and existing company technologies; develop new physics-based models for silicon bipolar & MOS devices & verify these models with computer simulations & experimental data; apply FABRICS to BiCMOS process. Performance of job duties requires extensive use of electrical and optical characterization tools such as Deep Level Transient Spectroscopy, Electron Beam Induced Current, & Scanning Electron Microscopy on silicon devices & material & a thorough knowledge of commonly used parametric analysis systems (such as current-voltage, capacitance-voltage systems). Requirements: Ph.D. in Electrical Engineering with emphasis in Solid State Device Physics & Device Characterization, & Silicon Processing. Grad-

ate studies/research must have included advanced concepts in the physics and modeling of silicon bipolar and MOS devices and in-depth experience with computer simulation of silicon devices, processes, & circuits. \$51,000 per year/40 hr wk. Job in Mesa, AZ. Qualified applicants send resume with ad by June 20th to AZ Job Service, Attn: 732A Re: 5679044, P.O. Box 6123, Phoenix, AZ 85005. Emp Pd Ad. Proof of authorization to work in U.S. required if hired.

Research Scientist: Will design holographic based non-linear optical signal processing and pattern recognition systems. Reqs.: Ph.D. in Electrical Engrg w/emphasis or specialization in Electro-Optics; 6 mo. research exp. in the development of holographic based real-time pattern recognition & signal processing systems, optical neural networks & optical interconnections; a 2+ publication record demonstrating solid theoretical & practical knowledge of optical computing & neural network systems; proficiency w/C & Lisp & in operating LCTV, MOD & FLC devices. \$50K/yr; Job site/interviews: Torrance, CA. Submit resume to Job MD21153, PO Box 9560, Sacramento, CA 95823-0560 no later than 7/1/91.

Author wanted: Engineering publisher seeks knowledgeable, experienced professional in the electrical engineering field to write/compile a book of solved problems. Advance + royalties. Write Jason Standifer, Professional Publications, 1250 Fifth Ave., Belmont, CA 94002. or call 800-426-1178.

Application Engineer, Fort Wayne, Indiana, 8-4PM, 40Hrs/wk, \$15.11/Hr, duties—software math oriented algorithms; R&D of controls in industrial applications involving material handling, drill tables, paintings, instrumentation, CAD drawings, repair of computer boards, design of computer boards, building and designing test fixtures in & for computer applications. BSEE/T required. Extensive knowledge in math used for writing software algorithms. Resume with social security no. Sent to: Indiana State Employment & Training Services, 10 N. Senate Ave., Indianapolis, Indiana 46204, Attn: W.F. Shepard. Refer to I.D. 3288152.

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Program notes

(Continued from p. 20)

to its developers, in addition to punctuation and many math and special symbols. Even Chinese, Japanese, and Korean are within its reach, though Chinese alone requires over 30 000 characters. However, after studying the official ideogram listings of China, Japan, Korea, and Taiwan, linguists determined that about two-thirds of their ideograms are common to all or most of them. When the common ideograms are not duplicated, everything fits in the 64K character space.

In November 1990, after five years of work, a final draft was submitted to the consortium members, who incorporated the effort as Unicode Inc. in January. The review process ended in February. A standard ready for implementation is to be published in June 1991, according to Mike Kurnaghan of Metaphor Computer Systems, another of the consortium's members. Contact: Ken Whistler, Metaphor Computer Systems, 1945 Charleston Rd., Mountain View, Calif. 94043; 415-961-3620; or circle 104.

COORDINATOR: Dennis L. DiMaria

CONSULTANTS: Stuart I. Feldman, Bellcore, Computer Systems Research; John Kellum, Intergraph Advanced Processor Division

INSTITUTE OF MICROELECTRONICS (SINGAPORE)

As part of our drive towards the 21st century, we are setting up the Institute of Microelectronics as a national R & D laboratory with a staff strength of 150 by 1995. To be housed in a new building of 6,600 sq m in the vicinity of the Science Park and the National University of Singapore, the Institute will be an active R & D partner to the microelectronics industry.

We are currently looking for Senior Members and Members Technical Staff in the areas indicated below. We have also a limited number of openings for R&D Managers in the same areas.



Silicon Processing Technology

The emphasis of this group is to support and complement the local wafer fabrication companies producing IC's using MOS technologies 1.25 um and better. Specific responsibilities include the development of selected processing technology modules and the characterization of new and existing processing technologies.

Candidates for this group must have hands-on experience in laboratories for module development and a good understanding of processing integration into the manufacturing environment.

This group has the responsibility of identifying and realizing prototypes of board-level products which have high potential in the market place. Technological and industrial skills sets needed for the MSA group include computer architecture and design, computer networking/LANs, image processing (color, video, compression/decompression, algorithms), and manufacturing systems and components.

Experience and background in customer support and interfacing, systems requirements development, VLSI and/or board level design and demonstrated ability to deliver are strong pluses.

Reliability and Failure Analysis

This group will focus on R & D in failure analysis and modelling of failed components from field returns and factory tests, in reverse engineering of components and sub-assemblies, in developing component screening procedures, in component yield enhancement, packaging and PWB reliability assessment, and reliability consulting.

Specific experience and background in FMECA and FTA reliability analyses, semiconductor processing and failure analysis, or PWB manufacturing or component/assembly packaging, coupled with a positive attitude is required.

Microelectronic Systems and Applications

This group has the responsibility of identifying and realizing prototypes of board-level products which have high potential in the market place. Technological and industrial skills sets needed for the MSA group include computer architecture and design, computer networking/LANs, image processing (color, video, compression/decompression, algorithms), and manufacturing systems and components.

Experience and background in customer support and interfacing, systems requirements development, VLSI and/or board level design and demonstrated ability to deliver are strong pluses.

VLSI Circuit Design and Test & CAD

Concepts and architectures developed at the Institute will be captured by this group through VLSI circuit design and test, with an emphasis toward mixed analog and digital designs, and through the use of CAD, to which the group's main role is to evaluate and integrate tools and to interface with CAD suppliers to obtain new capabilities.

We are looking for professionals with experience/background in VLSI design and CAD with emphases on the ability to innovate and deliver in a team environment.

An attractive and comprehensive remuneration package which includes settling-in allowance, subsidised housing, educational allowance, passage assistance and medical benefits will be offered.

Applicants should send a two-page resume with a brief covering letter to :

Director, IME Faculty of Engineering National University of Singapore 10 Kent Ridge Crescent Singapore 0511 Fax : 7773847 E-Mail : FENGHC @ NUS 3090	or International Advisor P.O.Box 373 Martinsville, N.J. 08836 USA Fax : 908-722-6027
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Please apply before September 1, 1991. Applications will be processed as soon as they are received.

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Scanning The Institute

'Emergency' broadcast

A satellite program broadcast to the entire United States in late February dealt with the communications and other technologies and services needed to respond to emergencies. The nine-hour presentation was viewed by over 150 groups—companies, colleges, government agencies, and broadcasting stations. It was one of a series of pilot programs produced by National Broadcast Satellite Corp. of New York City to ascertain how the service can meet businesses' needs [THE INSTITUTE, May/June, p. 1].

Satellites for Korea

Development plans are being finalized for a South Korean scientific satellite and a communications and broadcasting satellite, scheduled for launch in May 1993 and in 1995, respectively. The payload of the first will include high-energy-particle detection equipment. The second will have 5300 voice circuits, three television broadcasting channels, and four video channels [THE INSTITUTE, May/June, p. 4].

Asian 'presence' in the Gulf

Japanese components developed as commercial items but with military applications must have shown up in much of the advanced technology employed in the Gulf war. Ceramic packages for semiconductors, many of which are made by Kyoto's Kyocera Corp., would have been a major contribution [THE INSTITUTE, May/June, p. 8].

European supercomputer proposed

A 10-year, US \$14 billion program to build a Europe-wide high-speed computer network, as well as a supercomputer capable of 10^{12} floating-point operations per second, has been proposed by a panel assembled by the European Commission, the European Community's executive arm. Funding would be split between government and industry [THE INSTITUTE, May/June, p. 6].

Esaki gets IEEE Medal of Honor

The IEEE's 1991 Medal of Honor "for contributions to and leadership in tunneling, semiconductor superlattices, and quantum wells" will go to Leo Esaki (F), who discovered the first quantum electronic device, the tunnel diode. A 1973 Nobelist in physics, he is an IBM Fellow at the Thomas J. Watson Research Center, Yorktown Heights, N.Y. [THE INSTITUTE, May/June, p. 12].

Polaroid inventor dies

Edwin H. Land (HM), who in 1948 invented the instant camera, died March 1 at age 81. Land held 533 patents. While head of

Polaroid Corp. for many years, he also found time to advise the U.S. government on military matters. After his retirement at age 71, he founded the Rowland Institute for Science in Cambridge, Mass., which recently developed a microscopic laser for the manipulation of single-celled organisms such as bacteria [THE INSTITUTE, May/June, p. 10].

Coming in Spectrum

Concurrent engineering. Now taking hold at leading manufacturers, this approach to new product development compels designers to consider a product's entire life cycle, from concept through manufacturing, testing, and customer service. It also demands that the customer's needs be factored into the design process from the start. This special report will consist of an introduction and several parts.

• **Implementation.** Concurrent engineering requires a thorough rethinking of how projects are organized. The ideal organization facilitates close communication among all those bringing a new product to market—including people on the production line and logistics and maintenance experts. Relationships with suppliers and customers must also be factored in.

• **The Defense Department's Input.** The Defense Advanced Research Projects Agency is promoting concurrent engineering for the Department of Defense. The agency has even set up a think tank on the subject at the University of West Virginia. A leader in that program tells what it has accomplished so far.

• **CAD Framework Initiative.** This recently organized initiative is hard at work on specifications that will allow multiuser computer-aided design (CAD) tools from different vendors to exchange design data.

• **Methods and techniques.** Though still young, concurrent engineering has acquired its own terminology, well worth a rapid review.

• **Case histories.** Small and large organizations are already benefiting from the concurrent engineering approach, as is clear from the experiences of different types of manufacturers—among them a Hewlett-Packard division, Raytheon, and a Litton division.

Floating point and the PC. Math coprocessors provide personal computers with hardware support for floating-point arithmetic. But there is more to installing one than simply plugging it into a socket on a printed-circuit board. Questions of compatibility with both the central processing unit and the intended application must be answered.

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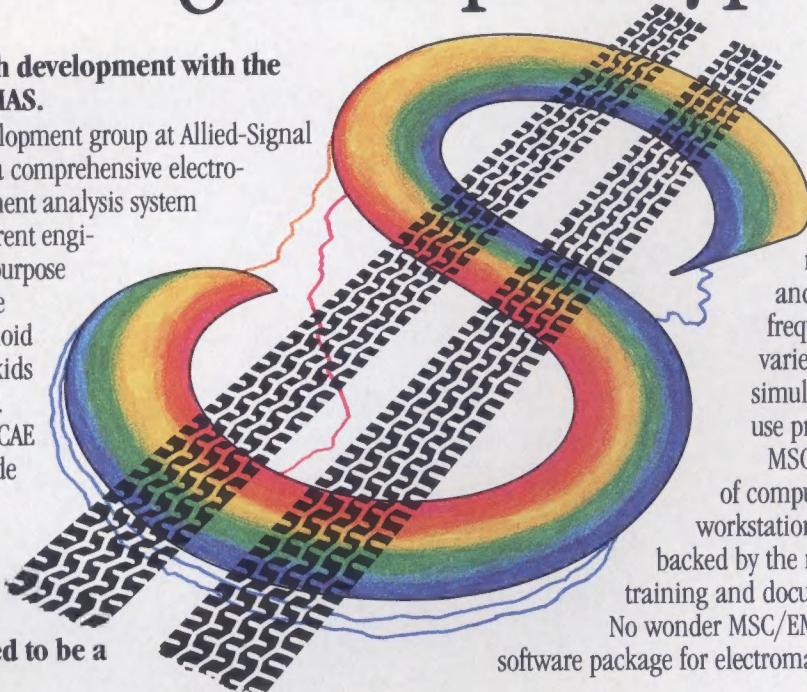
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